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1962-1963

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Editor

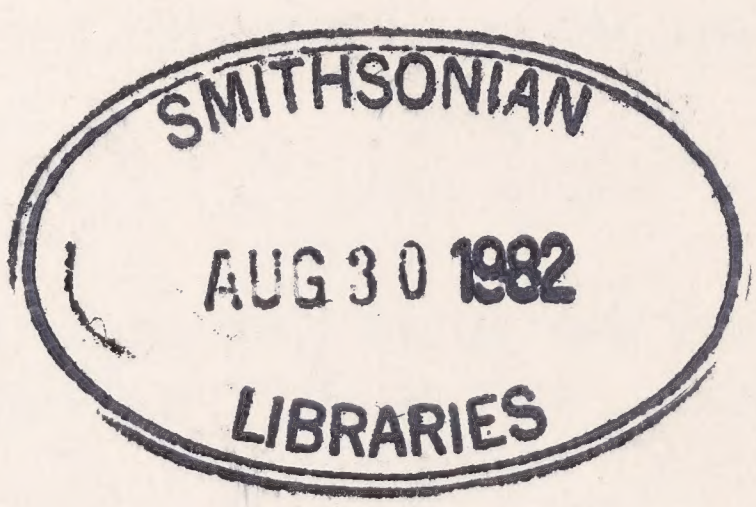
TULANE UNIVERSITY OF LOUISIANA
New Orleans

TULANE STUDIES IN GEOLOGY

VOLUME 1

1962-1963

HUBERT C. SKINNER
Editor



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CONTENTS

VOLUME 1

NUMBER PAGE

1. ARKADELPHIA FORAMINIFERIDA

Hubert C. Skinner 1

2. STUDIES ON TERTIARY AND RECENT GIANT LIMIDAE

Harold E. Vokes 75

3. CENOZOIC MURICIDAE OF THE WESTERN ATLANTIC REGION, PART I—MUREX *sensu stricto*

Emily H. Vokes 95

4. GEOLOGY OF THE CAÑON DE LA HUASTECA AREA IN THE SIERRA MADRE ORIENTAL, NUEVO LEON, MEXICO

Harold E. Vokes 127

A NEW SPECIES OF FORAMINIFERIDA FROM THE MIOCENE OF SOUTH LOUISIANA

Hubert C. Skinner 149

NOTES ON CENOZOIC MURICIDAE FROM THE WESTERN ATLANTIC REGION, WITH DESCRIPTIONS OF NEW TAXA

Emily H. Vokes 151

TULANE STUDIES IN GEOLOGY is devoted primarily to the geology and paleontology of the coasts and adjacent land areas of the Gulf of Mexico and the Caribbean Sea. Each number is issued separately and contains an individual monographic study, or several minor studies. As volumes are completed, title pages and tables of contents will be distributed to institutions exchanging the entire series.

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U.S.A.

TULANE STUDIES IN GEOLOGY

Volume 1, Number 1 August 31, 1962

ARKADELPHIA FORAMINIFERIDA

HUBERT C. SKINNER
PROFESSOR OF GEOLOGY
TULANE UNIVERSITY

CONTENTS

		Page
I.	Abstract	1
II.	Introduction	1
III.	Procedure	1
IV.	Stratigraphy	1
V.	Summary	2
VI.	Acknowledgments	3
VII.	Description of Foraminiferida	3
	References	51
	Plate I	55
	Plate II	57
	Plate III	59
	Plate IV	61
	Plate V	63
	Plate VI	65
	Index to Synonymies	67

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ARKADELPHIA FORAMINIFERIDA

HUBERT C. SKINNER

PROFESSOR OF GEOLOGY
TULANE UNIVERSITY

I. Abstract

The prolific foraminiferal fauna of the upper Cretaceous Arkadelphia Marl (southwestern Arkansas) is described and illustrated. Previous literature on the Foraminiferida of the Arkadelphia is scattered and confused. All 118 known species from the formation are re-described and numerous taxonomic revisions are made to correct generic assignments in conformity with modern usage. Twenty-four other species-groups which have been reported from the Arkadelphia by earlier writers are reviewed and discussed. It is suggested that most of these are erroneously attributed to this horizon. A range chart and a brief discussion of the faunal zones within the formation are included.

The fauna of the Arkadelphia indicates that it may be correlated with the Navarro Formation of Texas, The Monmouth Formation of Maryland, the Navesink and Mount Laurel formations of New Jersey and the Maestrichtian group of the Senonian stage of the European Cretaceous.

II. Introduction

The upper Cretaceous Arkadelphia Marl of southwest Arkansas is prolific in microfossils. The Foraminiferida are distinctive and can be used to identify the formation both in surface and in subsurface occurrences.

Arkadelphia outcrops, 6.4 miles north of Hope, Hempstead County, Arkansas, afford the best exposed, most complete known surface section of the formation (see figure 1). These exposures consist of approximately 57 feet of marls and sandstones. The greatest known thickness (160 feet) is in the subsurface.

The previous literature concerning the fauna of the Arkadelphia is scattered and confused. All species known to the writer from this formation are re-described and other reported species are listed and discussed. A range chart and a brief discussion of faunal zones are included. The Ostracoda of the Arkadelphia have been the subject of an earlier paper (Skinner, 1956).

III. Procedure

The field work and geological reconnaissance required for this study were accomplished in 1952 and 1953. The specific outcrop of Arkadelphia Marl to be studied was selected, the section was measured and samples were collected at six-inch intervals from the unconformable contact with the underlying Nacatoch Sand to the top of the Arkadelphia where it is unconformably overlain by the Midway Formation. The samples were obtained either from fresh surface exposures or by hand auguring where fresh exposures were not available.

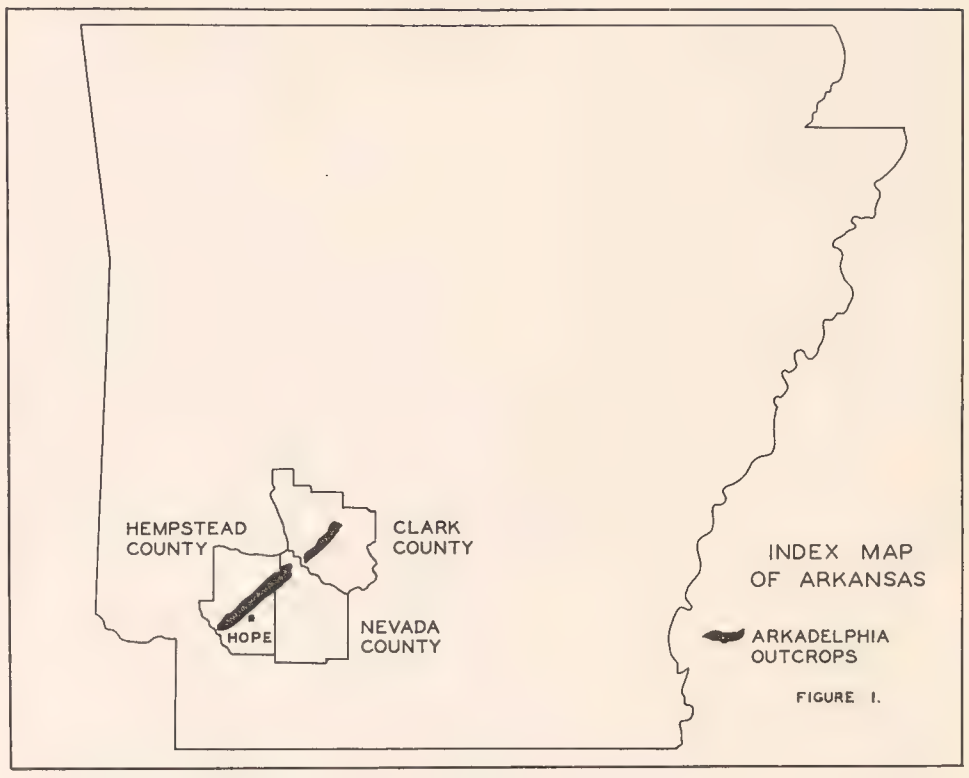

FIGURE 1.

The samples were washed by the double decantation method and the specimens were picked and mounted on faunule slides. The identified species were photographed with a Leitz Aristophot camera mounted over a Leitz Ortholux microscope at a magnification of 48 or 24 diameters, depending on the size of the specimens.

The hypotypes illustrated in this paper have been deposited in the United States National Museum (USNM), Washington, D. C.

IV. Stratigraphy

The name "Arkadelphia shales" was first used by Hill (1888, p. 53) for "blue clays and yellow sands, consisting of alternating bands of these materials, varying from one-eighth of an inch to one foot in thickness," exposed near Arkadelphia, Clark County, Arkansas. Hill believed these shales to be Tertiary in age. Harris (1894, p. 15) later identified equivalent exposures in Hemp-

stead and Clark counties as Cretaceous sediments. Veatch (1906, p. 28) designated "the dark, laminated clays which overlie the Nacatoch sand" as the Arkadelphia shales. This usage, somewhat modified from the original description, is accepted. Seven feet of poorly exposed Arkadelphia Marl at Arkadelphia and 22 feet of well exposed sandy marl underlain by a hard, basal sandy limestone north of Hope, Hempstead County, Arkansas, were described by Dane (1929). The latter exposures supplemented by hand augured samples, with a total thickness of approximately 57 feet, are the subject of the present study.

The Arkadelphia Marl, the youngest formation in Arkansas of the upper Cretaceous (Gulfian), consists chiefly of dark gray and black marls and marly clay, weathering light gray and containing some beds of hard, dense, calcareous, and highly fossiliferous gray sandstone, gray sandy clay, sandy limestone, dense concretionary limestone, and white impure chalk. The fresh surface commonly appears distinctly laminated or stratified.

The Arkadelphia overlies the Nacatoch Sand with clear unconformity. The base of the Arkadelphia where observed by the writer is channeled distinctly at the contact with the Nacatoch Sand, indicating a chronological break separating the two units. Lenses of hard, calcareous, fossiliferous, fucoidal sandstone mark the base in the area studied. The basal portion of the formation is not well exposed and was observed and sampled 18 feet below the surface in a water well. The Paleocene Midway Formation unconformably overlies the Arkadelphia with a thin limestone at the base of the Midway.

The Arkadelphia Marl weathers readily and good exposures are uncommon. The Arkadelphia permits development of a relatively low, smooth topography covered with brown sedge grass, briar thickets, some scrub oaks and pines, a contrast to the adjoining pine-clad hills of the Nacatoch Sand.

The microfauna is sparsely distributed in the lower, more sandy portion of the Arkadelphia, but is preserved in abundance in the upper portion.

V. Summary

1. One hundred and forty-two species-groups of Foraminiferida from seventy genus-groups have been reported from the Arkadelphia. One hundred and eighteen species-groups were recovered from the measured section sampled by the writer. These have been illustrated and described.

2. The previous literature concerning the fauna of the Arkadelphia and its equivalents is scattered and confused. It is attempted here to summarize the earlier works by revising the fauna to conform to modern usage, and to re-describe all known species which are present in the formation. Twenty-four species have been reported which were not recovered by the writer. It is likely that most of these represent misidentified forms. These are as follows:

Reophax difflugiformis H. B. Brady
Gaudryina (Siphogaudryina) stephensoni Cushman
Clavulinoides compressus (Cushman)
Plectina watersi Cushman
Lenticulina (Lenticulina) jonesi Sandidge
Marginulina navarroana Cushman
Marginulina silicula (Plummer)
Chrysalogonium granti (Plummer)
Citharina navarroana (Cushman)
Pseudofrondicularia lanceola (Reuss)
Bolivinita costifera Cushman
Bolivina incrassata Reuss
Bolivina decurrens (Ehrenberg)
Siphogenerinoides brevispinosa Cushman
Bulimina prolixa Cushman and Parker
Tubitextularia cretacea (Cushman)
Planoglobulina acervulinoides (Egger)
Globotruncana arca (Cushman)
Globotruncana canaliculata (Reuss)
Globorotalia membranacea (Ehrenberg)
Anomalina nelsoni W. Berry
Stilostomella alexanderi (Cushman)
Pullenia minuta Cushman
Cibicides subcarinatus Cushman and Deaderick

3. The Foraminiferida of the Arkadelphia Marl indicate that it may be correlated with the Navarro Formation of Texas, the Monmouth Formation of Maryland, the Navesink and Mount Laurel formations of New Jersey and the Maestrichtian group of the Senonian stage of the European Cretaceous. The Ostracoda of the Arkadelphia support these correlations.

4. The faunal content of the Arkadelphia samples is influenced strongly by the presence of sandy zones and euhedral crystals of selenite in the basal portion of the formation. The marked scarcity of individuals, species, and genera in the basal samples appears to be related to a sandy environment and the presence of the selenite crystals suggests that secondary alteration may

FIGURE 2

OCCURRENCE OF SPECIES

Neoflabellina reticulata	—	—	x	—	—	x	x	x	—	—	x	—	—	—	—	—	—	—	x
Frondicularia inversa	—	—	—	—	—	x	—	—	—	—	—	—	—	—	—	—	x	x	—
Pseudofrondicularia arkadelphiana	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	x	—
Guttulina adhaerens	—	—	x	—	—	x	—	x	—	—	—	—	—	—	—	—	—	—	x
Globulina lacrima lacrima	—	—	x	—	—	x	x	x	—	x	x	—	—	—	—	x	x	x	x
Globulina lacrima subsphaerica	—	—	—	—	—	—	x	x	—	—	—	—	—	—	—	—	—	x	x
Globulina lacrima horrida	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	x	—	—
Globulina prisca	—	—	—	—	—	x	—	—	—	—	—	—	—	—	—	x	—	—	—
Pyrulina cylindroides	—	—	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Pseudopolymorphina cuyleri	—	—	—	—	—	x	x	x	x	x	—	—	—	—	—	x	—	—	x
Vitriwebbina biosculata	—	—	x	—	—	x	—	—	x	—	x	—	—	—	—	x	—	—	—
Ramulina arkadelphiana	—	—	x	—	—	x	x	x	x	x	x	x	x	x	—	x	x	x	x

FIGURE 2 — OCCURRENCE OF SPECIES

Number of feet above the base of the Arkadelphia

Name of Species	1-3	4-6	7-9	10-12	13-15	16-18	19-21	22-24	25-27	28-30	31-33	34-36	37-39	40-42	43-45	46-48	49-51	52-54	55-57
Ammodiscus cretaceus	—	—	—	—	—	—	—	x	—	—	—	—	—	—	—	x	—	—	x
Reophax difflugiformis arenulata	—	—	—	—	—	x	—	—	—	—	—	—	—	—	—	—	x	—	—
Reophax texana	—	—	x	—	—	x	x	x	x	x	x	x	x	x	—	—	—	—	x
Haplophragmoides calculus	—	—	x	—	—	x	x	x	x	x	—	x	x	x	—	—	—	—	—
Haplophragmoides glaber	x	x	—	—	—	x	x	x	x	x	x	x	x	x	—	—	—	—	—
Haplophragmoides rugosus	x	—	x	—	—	x	x	x	x	—	—	x	x	x	—	—	—	—	x
Haplophragmoides excavatus	x	x	x	—	—	x	x	x	x	x	x	x	x	x	—	—	—	—	—
Ammobaculites arenatus	—	—	—	—	—	—	x	—	—	—	—	—	—	x	—	—	—	—	—
Ammobaculites coprolithiformis	—	—	—	—	—	—	x	x	—	—	—	—	—	—	—	—	—	—	x
Ammobaculites texanus	—	—	—	—	—	—	x	—	—	—	—	—	—	—	—	—	—	—	—
Bolivinopsis rosula	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—
Spiroplectammina semicomplanata	x	—	x	—	—	—	—	—	—	—	—	—	—	—	—	x	x	—	—
Spiroplectammina semicomplanata juncea	x	—	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Trochammina texana	x	x	x	—	—	x	x	x	x	x	x	x	x	x	—	—	—	—	—
Trochammina gyroides	x	x	x	—	—	x	x	x	x	x	x	x	x	x	—	—	x	—	—
Gaudryina deadericki	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—
Gaudryina navarroana	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—
Gaudryinella pseudoserrata	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	x	x	—
Gaudryinella pseudoserrata extensa	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	x	x	—
Pseudoclavulina arenata	x	—	—	—	—	x	x	x	x	x	x	x	x	x	—	—	—	—	—
Clavulinoides insignis	x	—	x	—	—	x	x	x	x	x	x	x	x	x	—	x	x	x	x
Marssonella oxycona	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—
Dorothia bulletta	—	—	x	—	—	—	x	—	—	—	—	—	—	—	—	x	x	x	x
Dorothia conula	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	x	x	x
Goesella rugulosa	—	—	x	—	—	x	x	x	x	x	x	x	x	x	—	—	x	—	x
Quinqueloculina sp.	—	—	—	—	—	—	—	x	—	—	—	—	—	—	—	—	x	—	—
Lagena hispida	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—
Lagena sulcata semiinterrupta	—	—	x	—	—	—	—	—	—	—	x	—	—	—	—	—	—	—	—
Lenticulina rotulata	—	—	—	—	—	x	x	x	x	x	x	x	x	x	—	—	x	—	x
Lenticulina navarroensis	x	—	—	—	—	x	x	x	x	x	x	x	x	x	—	x	x	x	x
Lenticulina navarroensis extruatus	x	—	x	—	—	x	x	x	x	x	x	x	x	x	—	x	x	x	x
Lenticulina pondi	—	—	—	—	—	x	x	x	x	x	x	x	x	—	—	—	x	—	x
Lenticulina spissocostatus	—	—	—	—	—	x	x	x	x	x	x	x	—	—	—	—	x	x	—
Lenticulina muensteri	—	—	—	—	—	x	x	x	x	x	x	x	x	x	—	x	x	x	x
Darbyella sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—
Planularia dissona	—	—	—	—	—	—	—	x	—	—	—	—	—	—	—	x	—	—	—
Planularia deadericki	—	—	—	—	—	x	x	x	—	—	—	—	—	x	—	x	x	x	—
Marginulina sp.	—	—	x	—	—	—	—	—	x	—	—	—	—	—	—	—	—	—	—
Marginulina plummerae	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—
Marginulina curvatura	—	—	—	—	—	—	x	—	—	x	—	—	—	—	—	—	—	—	—
Marginulina siliqua	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—
Dentalina legumen	—	—	—	—	—	x	x	x	—	—	—	—	—	—	—	—	x	x	—
Dentalina gracilis	—	—	—	—	—	x	x	x	—	x	—	—	—	—	—	x	x	x	—
Dentalina lorneiana	x	—	—	—	—	x	x	x	—	x	—	—	—	x	—	x	x	x	—
Dentalina aculeata	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—
Dentalina catenula	—	—	—	—	—	x	x	—	—	x	x	—	—	—	—	x	—	x	—
Dentalina basiplanata	—	—	—	—	—	x	x	x	—	x	x	—	—	—	—	—	x	x	—
Dentalina crinita	—	—	—	—	—	x	x	x	—	x	x	—	x	—	—	—	—	—	x
Dentalina delicatula	—	—	—	—	—	x	—	x	x	—	—	x	—	—	—	—	—	—	—
Nodosaria vertebralis	—	—	—	—	—	—	x	x	—	—	—	—	—	—	—	—	—	—	x
Nodosaria affinis	—	—	—	—	—	x	x	x	x	—	—	—	—	—	—	—	—	—	x
Nodosaria obscura	—	—	—	—	—	x	—	—	—	—	x	—	—	—	—	—	x	—	—
Chrysalogonium texanum	—	—	x	—	—	x	x	x	x	x	—	—	—	—	—	—	x	—	x
Pseudonodosaria larva	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	x
Rectoglandulina appressa	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	x
Rectoglandulina lagenoides	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—
Rectoglandulina pygmaea	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—
Saracenaria triangularis	—	—	x	—	—	—	x	—	—	—	—	—	—	—	—	—	—	—	—
Saracenaria saratogana	—	—	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Vaginulina cretacea	—	—	x	—	—	x	x	x	x	x	x	x	x	x	—	—	—	—	x
Citharina multicostata	—	—	x	—	—	—	—	x	—	—	x	—	—	—	—	—	—	—	—
Citharina barcoensis	—	—	—	—	—	—	—	x	—	—	—	—	—	—	—	—	—	—	—
Citharina simondsi	—	—	—	—	—	—	x	x	—	x	—	—	—	—	—	—	x	x	—
Citharina webbervillensis	—	—	x	—	—	x	x	x	x	—	—	—	—	x	—	—	—	—	x
Neoflabellina rugosa	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—	—	—	—	—
Neoflabellina reticulata	—	—	x	—	—	x	x	x	—	—	x	—	—	—	—	—	—	—	x
Frondicularia inversa	—	—	—	—	—	x	—	—	—	—	—	—	—	—	—	—	x	x	—
Pseudofrondicularia arkadelphiana	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	x	—
Guttulina adhaerens	—	—	x	—	—	x	—	x	—	—	—	—	—	—	—	—	—	—	x
Globulina lacrima lacrima	—	—	x	—	—	x	x	x	—	x	x	—	—	—	—	x	x	x	x
Globulina lacrima subsphaerica	—	—	—	—	—	—	x	x	—	—	—	—	—	—	—	—	—	x	x
Globulina lacrima horrida	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	x	—	—
Globulina prisca	—	—	—	—	—	x	—	—	—	—	—	—	—	—	—	x	—	—	—
Pyrulina cylindroides	—	—	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Pseudopolymorphina cuyleri	—	—	—	—	—	x	x	x	x	x	—	—	—	—	—	x	—	—	x
Vitriwebbina biosculata	—	—	x	—	—	x	—	—	x	—	x	—	—	—	—	x	—	—	—
Ramulina arkadelphiana	—	—	x	—	—	x	x	x	x	x	x	x	x	x	—	x	x	x	x
Ramulina globotubulosa	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—
Buliminella cushmani	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	x	—	—
Loxostomum cushmani	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—
Loxostomum gemma	—	—	x	—	—	x	x	x	x	x	x	x	x	—	—	x	x	x	x
Loxostomum plaitum	—	—	—	—	—	x	x	x	x	x	x	x	—	x	—	x	x	x	x
Pseudouvigerina seligi	—	—	—	—	—	x	x	—	—	—	x	—	—	x	—	x	x	—	x
Siphogenerinoides plummeri	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	x	—
Bulimina aspera	x	—	—	—	—	x	x	x	—	—	—	—	—	—	—	—	x	x	x
Bulimina arkadelphiana	—	—	—	—	—	x	x	x	x	x	x	x	x	—	—	—	—	x	x
Gyroidina depressa	—	—	x	—	—	x	x	x	x	x	x	—	x	x	—	—	x	—	x
Gyroidina arkadelphiana	—	—	—	—	—	x	x	x	—	—	—	—	—	—	—	—	x	—	x
Stensioina americana	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—
Siphonina prima	—	—	—	—	—	x	—	—	—	—	x	—	—	—	—	—	x	—	—
Guembelitria cretacea	—	—	—	—	—	x	—	x	—	x	—	—	—	x	—	x	x	x	—
Heterohelix plummerae	—	—	—	—	—	x	x	x	—	—	x	—	—	x	—	x	x	x	x
Heterohelix striata	—	—	—	—	—	x	x	x	—	x	x	x	x	x	—	x	x	x	x
Heterohelix globulosa	—	—	x	—	—	x	x	x	x	x	x	—	x	x	—	—	x	x	x
Pseudoguembelina costulata	—	—	—	—	—	—	x	x	—	x	x	x	x	x	—	x	x	x	x
Pseudotextularia elegans	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—
Racemiguembelina fructicosa	—	—	—	—	—	—	x	—	—	—	—	—	—	—	—	—	x	—	—
Planoglobulina carseyae	—	—	—	—	—	x	x	—	—	—	—	—	—	x	—	x	x	—	—
Planoglobulina glabrata	—	—	—	—	—	—	x	—	—	—	—	—	—	—	—	—	—	—	—
Planoglobulina austinana	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—
Globotruncana cretacea	—	—	—	—	—	x	x	x	x	x	x	—	x	x	—	x	x	x	x
Globotruncana gansseri	—	—	—	—	—	x	x	x	x	x	x	x	x	—	—	—	x	—	x
Rugoglobigerina rugosa	—	—	—	—	—	x	x	x	x	x	x	x	x	—	—	x	x	x	x
Anomalina pseudopapillosa	x	x	—	—	—	x	x	x	x	x	x	x	x	x	—	x	x	x	x
Anomalinoides pinguis	—	—	—	—	—	x	x	x	x	—	x	—	x	—	—	—	x	—	—
Planulina correcta	x	—	—	—	—	x	x	x	x	x	x	x	x	x	—	x	x	x	x
Fursenkoina navarroana	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—
Stilostomella stephensoni	—	—	x	—	—	x	x	x	x	x	—	—	—	—	—	—	x	—	—
Stilostomella stephensoni speciosa	—	—	—	—	—	x	x	x	x	x	—	—	—	—	—	—	—	—	—
Stilostomella alexanderi impensia	—	—	—	—	—	x	x	x	—	x	—	—	—	—	—	—	—	—	x
Allomorphina navarroana	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—
Nonionella robusta	—	x	—	—	—	x	—	—	—	—	—	—	—	—	—	—	x	—	—
Nonionella ansata	—	—	—	—	—	x	—	—	—	—	—	—	—	—	—	x	x	—	—
Pullenia americana	—	—	—	—	—	—	—	x	—	—	—	—	—	—	—	—	x	—	—
Pseudoparrella glabrata	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—
Pseudoparrella navarroana	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—
Cibicides harperi	x	—	—	—	—	x	x	—	—	—	—	—	—	—	—	x	—	—	—
Cibicides beaumontianus	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—

have destroyed some of the fossils in the lower portion. A marked increase in forms is noted about 17 or 18 feet above the base and the abundant and well preserved fauna which is characteristic of the Arkadelphia is present throughout the remainder of the sequence.

5. Forty-nine of the species present in the Arkadelphia are restricted to the Navarro and equivalents. Twelve of these are characteristic of only the Arkadelphia and the upper Navarro and serve as index fossils:

Ammobaculites arenatus Cushman
Ammobaculites texanus Cushman
Gaudryina deadericki Cushman
Gaudryina navarroana Cushman
Gaudryinella pseudoserrata extensa Cushman
Pseudoclavulina arenata (Cushman)
Planularia deadericki Cushman
Marginulina curvatura Cushman
Pseudofrondicularia arkadelphiana (Cushman)
Bulimina arkadelphiana Cushman and Parker
Gyroidina arkadelphiana Cushman
Globotruncana gansseri Bolli

Thus, relatively few species are restricted to the Arkadelphia. Most Navarro species range from their first appearance throughout the remainder of the Navarro, becoming extinct at the close of the Cretaceous. Thus, only the few species which first appear in Arkadelphia time are distinctive of the Arkadelphia and equivalents.

6. Many Arkadelphia species are long-ranging and occur at many localities. An example is *Globotruncana cretacea* Cushman, which has been reported from at least 23 formations and 73 localities.

7. Taxonomic revisions have been made as follows: 1) *Robulus* is considered a subgenus of *Lenticulina* Lamarck, 2) *Darbyella* Howe and Wallace is emended to include species with a robuline aperture, and 3) at least ten species have been removed to other genera from their previous assignments.

VI. Acknowledgments

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VII. Description of Foraminiferida

The Loeblich and Tappan classification of the Foraminiferida (1961a) is followed in the systematic descriptions.

Order Foraminiferida Zborzewski, 1834

Superfamily Ammodiscacea Reuss, 1862

Family Ammodiscidae Reuss, 1862

Subfamily Ammodiscinae Reuss, 1862

Genus Ammodiscus Reuss, 1862

Ammodiscus Reuss, 1862, Akad. Wiss. Wien, Math.-naturw. Kl., Sitzb., vol. 44 (Jahrgang 1861), p. 365.

Type species: Ammodiscus infimus Bornemann, 1874, (not *Orbis infimus* Strickland, 1846). Subsequent designation by Loeblich and Tappan, 1954, emended, 1961b. *Gender:* masculine.

Discussion: For a complete discussion of *Ammodiscus* Reuss, see Loeblich and Tappan (1961b).

Ammodiscus cretaceus (Reuss)
Pl. I, fig. 3

Operculina cretacea Reuss, 1845, Versteiner. böhm. Kreidefm., pt. 1, p. 35, pl. 13, figs. 64, 65.
Cornuspira cretacea (Reuss). Reuss, 1860, Akad. Wiss. Wien, Math.-naturw. Kl., Sitzb., vol. 40, p. 177, pl. 1, fig. 1.
Cornuspira involvens (Reuss). W. Berry, 1929, (*not* Reuss), *in* Berry and Kelley, U. S. Natl. Mus., Proc., vol. 76, art. 19, p. 15, pl. 1, fig. 15.
Ammodiscus cretacea (Reuss). Cushman, 1934, Cushman Lab. Foram. Res., Contr., vol. 10, pt. 2, p. 45.
Ammodiscus cretaceus (Reuss). Cushman and Todd, 1943, Cushman Lab. Foram. Res., Contr., vol. 19, pt. 3, p. 51, pl. 9, fig. 1.
Ammodiscus cretaceus (Reuss) Cushman. Cushman, 1946, U. S. Geol. Survey, Prof. Paper 206, p. 17, pl. 1, fig. 35. (synonymy).
Ammodiscus cretaceus (Reuss). Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 59, pl. 1, fig. 15.

Diagnosis: Test planispiral, the many whorls closely coiled, slightly involute, commonly with

distinct radial creases or constrictions and typically distorted in fossilization; tubular second chamber increases gradually and uniformly in size, suture distinct, depressed; wall agglutinated, composed of extremely fine particles with an excess of cement, smooth, appearing polished, normally white and fairly thick; aperture, the open end of the tubular chamber.

Figured specimen: USNM 639431, maximum diameter 0.625 mm, collected 10 feet below the top of the Arkadelphia marl. Compared with plesiotypes in USNM: well within the range of variation.

Discussion: This species is widely distributed in the upper Cretaceous of North America. It has been reported from Manitoba, Canada; Estado de San Luis Potosi, Mexico; the Austin and Taylor groups of Texas; the Navarro (age) of Texas, Arkansas and Tennessee; and, the Pierre shale of Nebraska. In Europe it is reported from the lower Cretaceous Gault to the upper Cretaceous Senonian, but is considered most characteristic of the Turonian and lower Senonian (Cushman, 1946).

A. cretaceus (Reuss) was first noted in the samples 22 feet above the base of the Arkadelphia marl.

Superfamily Lituolacea Lamarck, 1809

Family Aschemonellidae Eimer and Fickert, 1899

Subfamily Reophacinae Cushman, 1910

Genus Reophax Montfort, 1808

Reophax Montfort, 1808, Conch. Syst., vol. 1, p. 331.

Type species: Reophax scorpiurus Denys de Montfort, 1808. Original designation. *Gender:* feminine.

Discussion: Proteonina fusiformis Williamson, the type species (subsequent designation, Rhumbler, 1904, p. 244) of *Proteonina* Williamson, 1858, has been shown to be multilocular (Brady, 1884, p. 291; Loeblich and Tappan, 1955, p. 8), and *Proteonina* has been suppressed (Loeblich and Tappan) as a junior synonym of *Reophax* Montfort.

Reophax difflugiformis H. B. Brady

Reophax difflugiformis H. B. Brady, 1879, Quart. Jour. Micros. Sci., vol. 19, p. 51, pl. 4, figs. 3a, b.

?Haplophragmium lagenarium Berthelin, 1880, Soc. Géol. France, Mém., sér. 3, tome 1, no. 5, p. 21, pl. 1, figs. 2a, b.

Reophax difflugiformis H. B. Brady. H. B. Brady, 1882, Roy. Soc. Edin., Proc., vol. 11, p. 715.

Reophax difflugiformis H. B. Brady. H. B. Brady, 1884, Challenger, Rept., Zoology, vol. 9, p. 289, pl. 30, figs. 1-3 (*not* figs. 4, 5).

Proteonina difflugiformis lagenarium (Berthelin). Millett, 1899, Roy. Micros. Soc., Jour., p. 253 *(partim).*

Proteonina difflugiformis (H. B. Brady). Rhumbler, 1904, Archiv. Protistenk., vol. 3, p. 245 *(partim).*

Proteonina difflugiformis-lagenarium (Berthelin). Rhumbler, 1904, Archiv. Protistenk., vol. 3, p. 246, fig. 80c.

Proteonina difflugiformis (H. B. Brady). Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 15 *(partim).* (synonymy).

Reophax difflugiformis H. B. Brady. Barker, 1960, Soc. Econ. Paleont. Mineral., Spec. Pub. 9, p. 62, pl. 30, figs. 1-3 (*not* fig. 4).

Reophax difflugiformis H. B. Brady. Skinner, 1961, Jour. Paleontology, vol. 35, no. 6, p. 1239.

Diagnosis: Test free, a single, undivided chamber, rounded or oval in transverse section; wall agglutinated, composed of fine quartz grains firmly cemented on a chitinous base, exterior nearly smooth; aperture simple, terminal, elevated on a short produced neck.

Reophax difflugiformis arenulata Skinner

Pl. I, fig. 1

Reophax difflugiformis H. B. Brady. H. B. Brady, 1884, Challenger, Rept., Zoology, vol. 9, p. 290, pl. 30, fig. 5 (*not* figs. 1-4).

Reophax difflugiformis H. B. Brady. Flint, 1899, U. S. Natl. Mus., Rept. (for 1897), pt. 1, p. 272, pl. 16, fig. 2.

Proteonina difflugiformis (H. B. Brady). Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 15 *(partim),* pl. 1, figs. 7, 8. (synonymy, *partim).*

Proteonina atlantica Cushman. Parker (*not* Cushman), 1952, Harvard, Mus. Comp. Zool., Bull., vol. 106, no. 9, p. 393, pl. 1 fig. 2.

Proteonina atlantica Cushman. Bandy (*not* Cushman), 1953, Jour. Paleontology, vol. 27, no. 2, p. 177, pl. 21, figs. 5a, b.

Proteonina difflugiformis (H. B. Brady). Friz-zell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 57, pl. 1, fig. 4.

Reophax atlantica (Cushman). Barker, 1960, Soc. Econ. Paleont. Mineral., Spec. Pub. 9, p. 62, pl. 30, fig. 5.

Proteonina difflugiformis (H. B. Brady). *auct.* (*partim*).

Reophax difflugiformis arenulata Skinner, 1961, Jour. Paleontology, vol. 35, no. 6, p. 1239.

Diagnosis: This form differs from the typical subspecies in that the test is larger and the wall is composed of relatively coarse sand grains. The neck is less pronounced in many specimens but others have been seen with a quite prominent neck.

Figured specimen: USNM 639432, length 0.26 mm, maximum diameter 0.24 mm, collected 17 feet above the base of the Arkadelphia marl.

Discussion: The Arkadelphia form is coarsely arenaceous with a clearly defined neck. It is probable that the neck is partially obscured on some specimens due to the coarseness of the wall. This subspecies is rare in the Arkadelphia, and the typical subspecies is not known from the formation.

Reophax texana Cushman and Waters

Pl. I, fig. 2

Reophax texana Cushman and Waters, 1927, Cushman Lab. Foram. Res., Contr., vol. 2, pt. 4, p. 82, pl. 10, fig. 2.
Reophax texanus Cushman and Waters. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 16, pl. 1, figs. 18-20. (synonymy).
Reophax texana Cushman and Waters. Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 58, pl. 1, fig. 13.

Diagnosis: Test generally rectilinear or somewhat arcuate, uniserial; chambers subspherical to spherical, slightly overlapping; wall agglutinated, of coarse angular sand grains with a minimum of cement, firmly fixed, surface somewhat roughened; aperture small, rounded or angled, central and terminal.

Figured specimen: USNM 639433, length 1.50 mm, maximum diameter 0.40 mm, collected 32 feet above the base of the Arkadelphia marl. Compared with the holotype in USNM: typical.

Discussion: This species occurs throughout the Gulf Coast, limited to the Navarro and equivalents. It is reported from the Kemp clay and Corsicana marl of Texas and the Prairie Bluff chalk of Mississippi and Alabama.

Family Lituolidae Lamarck, 1809

Subfamily Haplophragmoidinae Maync, 1952

Genus Haplophragmoides Cushman, 1910

Haplophragmoides Cushman, 1910, U. S. Natl. Mus., Bull. 71, pt. 1, p. 99.

Type species: Nonionina canariensis d'Orbigny, 1839. Original designation [cited as *Haplophragmium canariense* d'Orbigny]. *Gender:* masculine.

Haplophragmoides calculus Cushman and Waters

Pl. I, fig. 4

Haplophragmoides calcula Cushman and Waters, 1927, Cushman Lab. Foram. Res., Contr., vol. 2, pt. 4, p. 83, pl. 10, figs. 5a, b.
Haplophragmoides calcula Cushman and Waters. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 19, pl. 2, figs. 11, 12. (synonymy).
Haplophragmoides calculus Cushman and Waters. Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 59, pl. 1, figs. 26a, b.

Diagnosis: Test closely coiled, planispiral, quite strongly compressed, periphery slightly lobulate; chambers and sutures indistinct; wall agglutinated, of coarse sand grains with a considerable amount of cement, but roughly finished on the exterior; color typically dark greenish-black or iron-stained; aperture simple, basal.

Figured specimen: USNM 639434, maximum diameter 0.44 mm, collected 16 feet above the base of the Arkadelphia. Compared with the holotype in USNM: typical, but smaller and unstained.

Discussion: This species is common in the upper Navarro and equivalents in the Gulf Coast. Cushman (1946, p. 20) reports similar forms from the upper Taylor and Austin which may be immature individuals of *Ammobaculites*.

Haplophragmoides glaber Cushman and Waters

Pl. 1, fig. 5

Haplophragmoides glabra Cushman and Waters, 1927, Cushman Lab. Foram. Res., Contr., vol. 2, pt. 4, p. 83, pl. 10, figs. 6a, b.
Haplophragmoides glabra Cushman and Waters. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 20, pl. 2, figs. 16, 17. (synonymy).
Haplophragmoides glaber Cushman and Waters. Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 60, pl. 1, figs. 31a, b.

Diagnosis: Test closely coiled, planispiral, somewhat compressed, umbilicate, periphery rounded; chambers fairly distinct, 7 to 10 in the last-formed coil of the adult form, rounded; sutures slightly curved, slightly depressed; wall agglutinated, finely arenaceous, smoothly finished; color dark gray to white; aperture simple, basal.

Figured specimen: USNM 639435, maximum diameter 0.375 mm, collected 21 feet above the base of the Arkadelphia. Compared with the holotype in USNM: compares favorably.

Discussion: This species is common in the lower Arkadelphia. It apparently is

characteristic of the upper Navarro and equivalents in Arkansas and Texas. It also has been reported from Saskatchewan.

Haplophragmoides rugosus Cushman and Waters

Pl. I, fig. 6

Haplophragmoides rugosa Cushman and Waters, 1927, Cushman Lab. Foram. Res., Contr., vol. 2, pt. 4, p. 83, pl. 10, figs. 4a, b.
Haplophragmoides rugosa Cushman and Waters. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 20, pl. 2, figs. 18, 19. (synonymy).
Haplophragmoides rugosus Cushman and Waters. Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 60, pl. 2, figs. 2a, b.

Diagnosis: Test closely coiled, planispiral, slightly compressed, deeply umbilicate, periphery broadly rounded; 5 to 7 chambers in the last-formed coil, subspherical; sutures slightly depressed, radial; wall agglutinated, composed of coarse but rather neatly fitted angular sand grains; color normally dark; aperture simple, basal.

Figured specimen: USNM 639564, maximum diameter, 0.54 mm, collected from 16 feet above the base. Compared with the holotype in USNM: average specimen.

Discussion: This species is common in the Arkadelphia and is widely distributed in the Navarro and equivalents. Similar specimens are reported from the upper Taylor.

Haplophragmoides excavatus Cushman and Waters

Pl. I, fig. 7

Haplophragmoides excavata Cushman and Waters, 1927, Cushman Lab. Foram. Res., Contr., vol. 2, pt. 4, p. 82, pl. 10, figs. 3a, b.
Haplophragmoides excavata Cushman and Waters. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 21, pl. 2, figs. 13-15. (synonymy).
Haplophragmoides excavatus Cushman and Waters. Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 60, pl. 1, figs. 30a, b.

Diagnosis: Test closely coiled, planispiral, strongly compressed, periphery subacute; chambers distinct, 10 in the last-formed coil of the adult form, the borders of each chamber distinctly thickened, the central portion markedly depressed; sutures straight, radial, somewhat obscured; wall agglutinated, finely arenaceous, with a moderate amount of cement, smoothly finished; color light gray to white; aperture simple, basal.

Figured specimen: USNM 639436, maximum diameter 0.425 mm, collected 16 feet above the base. Compared with the holotype in USNM: typical.

Discussion: This form is common in the Arkadelphia marl and in the Kemp clay of Texas (Cushman, 1946, p. 21). It is also reported from the Taylor group of Texas. Examination of the holotypes of *H. glaber* Cushman and Waters and *H. excavatus* Cushman and Waters suggests to the writer that the two forms are conspecific and that the test of *H. excavatus* merely is collapsed.

Genus Ammobaculites Cushman, 1910

Ammobaculites Cushman, 1910, U. S. Natl. Mus., Bull. 71, pt. 1, p. 114.

Type species: Spirolina agglutinans d'Orbigny, 1846. Original designation [cited as *Ammobaculites agglutinans* (d'Orbigny)].
Gender: masculine.

Ammobaculites arenatus Cushman

Pl. I, fig. 8

Ammobaculites arenata Cushman, 1933, Cushman Lab. Foram. Res., Contr., vol. 9, pt. 3, p. 50, pl. 5, fig. 4.
Ammobaculites arenatus Cushman. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 22, pl. 3, fig. 5.

Diagnosis: Test elongate, strongly compressed; chambers and sutures indistinct, juvenarium closely coiled, adult rectilinear; wall agglutinated, composed of angular, coarse fragments with considerable cement, roughly finished; aperture obscure, but seems to be typical of genus.

Figured specimen: USNM 639437, length 0.65 mm, breadth 0.45 mm, collected 19 feet above the base. Compared with the holotype in USNM: typical, but later chambers broken off in this specimen.

Discussion: This species is reported only from the Arkadelphia marl. It is rare.

Ammobaculites coprolithiformis (Schwager)

Pl. I, fig. 9

Haplophragmium coprolithiforme Schwager, 1867, Benecke's Geogn.-päleont. Beitr., bd. 1, heft 3, p. 654, pl. 34, fig. 3.
Ammobaculites coprolithiforme (Schwager). Cushman, 1927, Royal Soc. Canada, Trans., ser. 3, vol. 21, sec. 4, p. 130, pl. 1, figs. 6, 7.
Ammobaculites coprolithiformis (Schwager) Cushman. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 22, pl. 3, fig. 9 (*not* figs. 7, 8). (synonymy).
Ammobaculites coprolithiformis (Schwager). Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 61, pl. 2, figs. 15a, b.

Diagnosis: Test elongate, juvenarium closely coiled, adult chambers rectilinear, uniform in width, circular in transverse section; sutures distinct, depressed; wall agglutinated, composed of coarse sand grains but smoothly finished; aperture of adult simple, rounded, terminal.

Figured specimen: USNM 639438, length 0.575 mm, breadth 0.275 mm, collected 19 feet above the base. Compared with plesiotypes in USNM: plesiotypes vary through a wide range but the Arkadelphia form agrees with the type description and compares favorably with the plesiotypes.

Discussion: This species ranges throughout the upper Cretaceous from the Eagle Ford group to the upper Navarro and equivalents, and is widely distributed in the Gulf Coast. It also is reported from Europe, western Canada and Trinidad.

Ammobaculites texanus Cushman

Pl. I, fig. 10

Ammobaculites texana Cushman, 1933, Cushman Lab. Foram. Res., Contr., vol. 9, pt. 3, p. 50, pl. 5, fig. 3.
Ammobaculites texanus Cushman. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 23, pl. 3, figs. 22, 23.
Ammobaculites texanus Cushman. Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 63, pl. 3, fig. 3. (synonymy).

Diagnosis: Test large, compressed, periphery rounded and lobulate, umbilicus excavated in the partially evolute adult form; chambers 5 or 6 in the last-formed coil of juvenarium, increasing in number in the adult as chambers become slightly inflated and more distinct; sutures indistinct, slightly depressed; wall agglutinated, composed of large grains with considerable cement, roughly finished in early stages, but becoming smoother in the adult; aperture obscured. Diameter of holotype 2.65 mm, thickness 0.60 mm.

Figured specimen: USNM 639439, length 1.175 mm, breadth 1.00 mm, collected 19 feet above the base. Compared with holotype in USNM: typical, but somewhat immature (with the adult stage incomplete).

Discussion: This species is known only from the Arkadelphia marl of Arkansas and the Corsicana marl of Texas.

Family Textulariidae Ehrenberg, 1839

Subfamily Spiroplectammininae Cushman, 1927

Genus Bolivinopsis Yakovlev, 1891

Bolivinopsis Yakovlev, 1891, Soc. nat. Univ. Imp. Kharkov, Trav., vol. 24, p. 349.

Type species: Bolivinopsis capitata Yakovlev, 1891. Monotypic. *Gender:* masculine.

Discussion: Recent authors (Sigal *in* Piveteau, 1952; Pokorný, 1958) consider *Bolivinopsis* Yakovlev an agglutinated form and the senior synonym of *Spiroplectammina* Cushman. However, Pokorný (1958, vol. I, p. 193) suggests that "it is *not impossible* that *Bolivinopsis* and *Spiroplectammina* are two independent isomorphous genera".

Bolivinopsis rosula (Ehrenberg)

Pl. V, fig. 8

Spiroplecta rosula Ehrenberg, 1854, Mikrogeologie, pl. 32, fig. 26. [The species-group name is a noun in apposition.]
Spiroplectoides rosula (Ehrenberg). Cushman, 1927, Cushman Lab. Foram. Res., Contr., vol. 3, pt. 1, p. 62, pl. 13, figs. 9a, b.
Bolivinopsis rosula (Ehrenberg). Macfadyen, 1933, Roy. Micros. Soc., Jour., vol. 53, p. 141.
Bolivinopsis rosula (Ehrenberg) Macfadyen. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 101, pl. 44, figs. 4-8. (synonymy).
Bolivinopsis rosula (Ehrenberg). Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 108, pl. 15, fig. 11.

Diagnosis: Test exceptionally elongate, quite slender, compressed; juvenarium closely coiled, planispiral, adult chambers biserial, of uniform size and shape, numerous; sides of test parallel; sutures distinct, extending obliquely backward; wall agglutinated, composed of fine particles, smoothly finished; aperture subterminal.

Figured specimen: USNM 639440, length (broken) 0.50 mm, breadth 0.15 mm, collected 8 feet below the top. Compared with numerous plesiotypes in USNM: compares favorably.

Discussion: This species is quite rare in the Arkadelphia. It is widely distributed through the Austin, Taylor, and Navarro and equivalents of Texas, Arkansas, Mississippi and Alabama.

Genus Spiroplectammina Cushman, 1927

Spiroplectammina Cushman, 1927, Cushman Lab. Foram. Res., Contr., vol. 3, pt. 1, p. 23.

Type species: Textularia agglutinans d'Orbigny var. *biformis* Parker and Jones, 1865. Original designation [cited as *Spiroplecta biformis* Parker and Jones]. *Gender:* feminine.

Discussion: Recent authors consider *Spiroplectammina* Cushman a junior synonym

of *Bolivinopsis* Yakovlev (see above discussion of *Bolivinopsis*).

Spiroplectammina semicomplanata (Carsey)

Pl. I, fig. 11

Textularia semicomplanata Carsey, 1926, Texas Bur. Econ. Geol., Univ. Texas, Bull. 2612, p. 25, pl. 3, fig. 4.
Textularia carinata var. *expansa* Plummer, 1927, Texas Bur. Econ. Geol., Univ. Texas, Bull. 2644, p. 67, pl. 3, fig. 3.
Spiroplectammina semicomplanata (Carsey). Plummer, 1931, Texas Bur. Econ. Geol., Univ. Texas, Bull. 3101, p. 129, pl. 8, fig. 7 (*not* fig. 8).
Spiroplectammina semicomplanata (Carsey) Plummer. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 28, pl. 6, figs. 5-14. (synonymy).
Spiroplectammina semicomplanata (Carsey). Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 67, pl. 4, figs. 18a, b.

Diagnosis: Test elongate, tapering, greatest breadth near the apertural end, thickest in the middle, periphery subacute, slightly lobulate; chambers distinct, not inflated, fairly high and overlapping, outer end broadly rounded, apertural face flattened; sutures distinct, slightly depressed, gently curved backward; wall agglutinated, finely arenaceous, smoothly finished, thin and delicate; aperture, a low narrow opening at the base of the apertural face.

Figured specimen: USNM 639441, length 0.34 mm, breadth 0.19 mm, collected two feet above the base. Compared with topotypes in USNM: typical.

Discussion: This form was described from a Navarro exposure on Onion Creek, near Austin, Texas, where most specimens including the holotype are crushed due to the thin delicate wall. The species is characteristic of the Navarro and equivalents and is recorded from the upper Taylor (Cushman, 1946). Similar forms occur in other parts of the Cretaceous.

Spiroplectammina semicomplanata juncea Cushman

Pl. I, fig. 12

Spiroplectammina anceps (Reuss). Cushman, 1931, (*not* Reuss), Jour. Paleontology, vol. 5, p. 299, pl. 34, figs. 2a, b.
Spiroplectammina semicomplanata (Carsey), var. *juncea* Cushman, 1932, Cushman Lab. Foram. Res., Contr., vol. 8, pt. 4, p. 95, pl. 11, figs. 10a, b.
Spiroplectammina semicomplanata (Carsey) Plummer var. *juncea* Cushman. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 29, pl. 6, fig. 15.

Diagnosis: This form differs from the typical subspecies in the quite elongate test with sides subparallel for most of the length; chambers numerous, spiral juvenarium clearly visible.

Figured specimen: USNM 639442, length 0.54 mm, breadth 0.19 mm, collected two feet above the base. Compared with holotype in USNM: typical, but smaller.

Discussion: The elongate subspecies has been recovered from the Saratoga chalk, the Nacatoch sand and the Selma chalk in addition to the Arkadelphia.

Family Trochamminidae Schwager, 1877

Genus Trochammina Parker and Jones, 1859

Trochammina Parker and Jones, 1859, Ann. Mag. Nat. Hist., ser. 3, vol. 4, p. 347.

Type species: Nautilus inflatus Montagu, 1808. Monotypic. *Gender:* feminine.

Trochammina texana Cushman and Waters

Pl. II, figs. 7, 8

Trochammina texana Cushman and Waters, 1927, Cushman Lab. Foram. Res., Contr., vol. 2, pt. 4, p. 85, pl. 11, figs. 8a-c.
Trochammina texana Cushman and Waters. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 50, pl. 15, figs. 4, 5. (synonymy).
Trochammina texana Cushman and Waters. Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 79, pl. 7, figs. 21a-c.

Diagnosis: Test trochoid, compressed, planoconvex; dorsal side flat or slightly concave; ventral side slightly convex, umbilicate; six chambers in the last-formed coil, adult chambers more distinct than earlier chambers; the dorsal borders of the adult chambers raised circumventing the central concave portion, the greatest ventral thickness is near the umbilical angle of each chamber; sutures on the dorsal side indistinct except between last two or three chambers, on the ventral side distinct and depressed; wall agglutinated, finely arenaceous, smoothly finished; aperture basal and ventral.

Figured specimen: USNM 639443, maximum diameter 0.50 mm, collected 16 feet above the base. Compared with the holotype in USNM: holotype is flatter and more delicate.

Discussion: This species is common in the upper Navarro and equivalents of the Gulf Coast.

Trochammina gyroides Cushman and Waters

Pl. II, figs. 9, 10

Trochammina gyroides Cushman and Waters, 1927, Cushman Lab. Foram. Res., Contr., vol. 2, pt. 4, p. 84, pl. 10, figs. 8a, b.
Trochammina gyroides Cushman and Waters. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 50, pl. 15, figs. 6a, b.
Trochammina gyroides Cushman and Waters. Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, pl. 7, figs. 16a, b.

Diagnosis: Test trochoid, thick, dorsal side flattened, ventral side strongly convex, periphery subacute; chambers distinct, normally six in the last-formed coil; sutures less distinct on the dorsal side where they are slightly depressed and gently curved; sutures radial, deeply depressed on the ventral side; wall agglutinated, finely arenaceous with much cement, smoothly finished; aperture ventral, narrow.

Figured specimen: USNM 639444, maximum diameter 0.50 mm, collected 8 feet below the top of the Arkadelphia. Compared with the holotype in USNM: compares favorably.

Discussion: The test of this species is much thicker than that of *T. texana* Cushman and Waters. It is common in the Arkadelphia.

Family Ataxophragmiidae Schwager, 1877

Subfamily Verneuilininae Cushman, 1911

Genus Gaudryina d'Orbigny, 1839

Gaudryina d'Orbigny, *in* de la Sagra, 1839, Hist. Phys. Pol. Nat. Cuba, Foraminifères, p. 109.

Type species: Gaudryina rugosa d'Orbigny, 1840. Subsequent designation, Cushman, 1911. *Gender:* feminine.

Subgenus Gaudryina *sensu stricto*

Gaudryina (Gaudryina) deadericki Cushman

Pl. I, fig. 13

Gaudryina deadericki Cushman, 1947, Cushman Lab. Foram. Res., Contr., vol. 23, pt. 3, p. 56, pl. 13, figs. 8-10.
Gaudryina deadericki Cushman. Cushman, 1949, U. S. Geol. Surv., Prof. Paper 221-A, p. 2, pl. 1, figs. 12, 13.

Diagnosis: Test small, juvenarium triserial, adult entirely biserial, much compressed, initial end subacute, periphery serrate; chambers increase rapidly in size as added, later ones slightly overlapping; sutures distinct, depressed, nearly straight, strongly oblique; wall agglutinated, finely arenaceous, smoothly finished; aperture elongate, basal at the inner margin of the last-formed chamber, a low opening in juvenarium, extending well into the apertural face in the adult test.

Figured specimen: USNM 639445, length 0.675 mm, breadth 0.38 mm, collected 8 feet below the top. Compared with the holotype and paratypes in USNM: typical.

Discussion: This species is known only from the Arkadelphia marl.

Gaudryina (Gaudryina) navarroana Cushman

Pl. I, figs. 14, 18

Gaudryina navarroana Cushman, 1932, Cushman Lab. Foram. Res., Contr., vol. 8, pt. 4, p. 98, pl. 11, figs. 15, 16.
Gaudryina navarroana Cushman. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 33, pl. 7, figs. 17a-c.
Gaudryina (Gaudryina) navarroana Cushman. Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 71, pl. 5, fig. 27.

Diagnosis: Test elongate, juvenarium triserial and sharply triangular, the edges bluntly angled, fusiform in front view; adult chambers biserial, somewhat compressed, lobed; sutures fairly distinct in juvenarium, distinct and depressed in adult; wall agglutinated, coarsely arenaceous, but smoothly finished; aperture, a deep re-entrant in the inner margin of the last-formed chamber with raised, rounded margins.

Figured specimens: USNM 639446 (fig. 14), length 0.69 mm, breadth 0.40 mm; USNM 639447 (fig. 18); collected 10 feet below the top. Compared with the holotype and paratypes in USNM: satisfactory, though not typical.

Discussion: This species is characteristic of the upper Navarro beds. It is distinguished by numerous triserial chambers contrasting with the few, somewhat flattened chambers of the short biserial stage. The thin wall of the test collapses easily and the sutures commonly appear as raised ridges.

Subgenus Siphogaudryina Cushman, 1935

Siphogaudryina Cushman, 1935, Smithsonian Misc. Colln., vol. 91, no. 21, p. 3.

Type species: Gaudryina stephensoni Cushman, 1928. Original designation. *Gender:* feminine.

Gaudryina (Siphogaudryina) stephensoni Cushman

Gaudryina stephensoni Cushman, 1928, Cushman Lab. Foram. Res., Contr., vol. 4, pt. 4, p. 108, pl. 16, figs. 6-8.
Gaudryina (Siphogaudryina) stephensoni Cushman. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 35, pl. 8, figs. 8-11. (synonymy).
Gaudryina (Siphogaudryina) stephensoni Cushman. Cushman, 1949, U. S. Geol. Surv., Prof. Paper 221-A, p. 3.
Gaudryina (Siphogaudryina) stephensoni Cushman. Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 71, pl. 5, figs. 24, 25.

Discussion: This species, reported by Cushman (1949) from the Arkadelphia, was not identified from the samples studied by the writer. The holotype and paratypes in USNM were examined.

Genus Gaudryinella Plummer, 1931

Gaudryinella Plummer, 1931, Amer. Midland Nat., vol. 12, p. 341.

Type species: Gaudryinella delrioensis Plummer, 1931. Original designation. *Gender:* feminine.

Gaudryinella pseudoserrata Cushman

Pl. I, fig. 15

Gaudryinella pseudoserrata Cushman, 1932, Cushman Lab. Foram. Res., Contr., vol. 8, pt. 4, p. 99, pl. 11, figs. 20. 21.
Gaudryinella pseudoserrata Cushman. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 36, pl. 8, figs. 15-21. (synonymy).
Gaudryinella pseudoserrata Cushman. Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 72, pl. 5, figs. 30, 31a, b.

Diagnosis: Test elongate, earliest portion triserial, then becoming biserial and somewhat compressed, adult stage tending to become uniserial; chambers distinct, becoming inflated and lobulate; sutures distinct, later ones deeply depressed; wall agglutinated, coarsely arenaceous, later portion of many specimens roughly finished; adult aperture rounded and subterminal.

Figured specimen: USNM 639448, length 0.56 mm, breadth 0.25 mm, collected 10 feet below the top. Compared with the holotype and paratypes in USNM: compares favorably, but smaller.

Discussion: This species is common and widely distributed in the Navarro and equivalents. There is considerable variation in the shape of the later chambers and the range of coarseness of the wall.

Gaudryinella pseudoserrata extensa Cushman

Pl. I, fig. 16

Gaudryinella pseudoserrata var. *extensa* Cushman, 1949, U. S. Geol. Surv., Prof. Paper 221-A, p. 3, pl. 1, figs. 15-17.

Diagnosis: This subspecies differs from the typical form in the smaller size, the more slender outline, and in the presence of more uniserial chambers in the adult test.

Figured specimen: USNM 639449, length 0.663 mm, breadth 0.175 mm, collected 8 feet below the top. Compared with the holotype and paratypes in USNM: typical.

Discussion: This subspecies is known only from the Arkadelphia marl. It is common and a guide fossil for the formation.

Genus Pseudoclavulina Cushman, 1936

Pseudoclavulina Cushman, 1936, Cushman Lab. Foram. Res., Spec. Pub. 6, p. 16.

Type species: Clavulina clavata Cushman, 1926. Original designation. *Gender:* feminine.

Pseudoclavulina arenata (Cushman)

Pl. I, fig. 17

Clavulina arenata Cushman, 1933, Cushman Lab. Foram. Res., Contr., vol. 9, pt. 3, p. 54, pl. 6, figs. 5a, b.
Pseudoclavulina arenata (Cushman). Cushman, 1937, Cushman Lab. Foram. Res., Spec. Pub. 7, p. 110, pl. 15, figs. 28a, b.
Pseudoclavulina arenata (Cushman) Cushman. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 37, pl. 9, fig. 9a, b.

Diagnosis: Test elongate, cylindrical; juvenarium triserial, somewhat triangular in cross-section; adult test uniserial; chambers somewhat indistinct, rather uniform in size except the final chamber which is typically longer; sutures indistinct, slightly depressed; wall agglutinated, coarsely arenaceous, surface rough; aperture terminal, rounded, without a neck.

Figured specimen: USNM 639450, length 0.75 mm, breadth 0.20 mm, collected 16 feet above the base. Compared with the holotype and paratypes in USNM: typical.

Discussion: This small, roughly finished species is known only from the Arkadelphia marl in Hempstead County, Arkansas, where it is abundant.

Genus Clavulinoides Cushman, 1936

Clavulinoides Cushman, 1936, Cushman Lab. Foram. Res., Spec. Pub. 6, p. 20.

Type species: Clavulina trilatera Cushman, 1926. Original designation. *Gender:* masculine.

Clavulinoides compressus (Cushman)

Clavulina compressa Cushman, 1928, Cushman Lab. Foram. Res., Contr., vol. 4, pt. 3, p. 61, pl. 8, figs. 1a-c, 2.
Clavulinoides compressa (Cushman). Cushman, 1937, Cushman Lab. Foram. Res., Spec. Pub. 7, p. 123, pl. 17, figs. 7-13.
Clavulinoides compressa (Cushman) Cushman. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 39, pl. 10, figs. 1-7. (synonymy).
Clavulinoides compressus (Cushman). Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 72, pl. 5, figs. 36a, b.

Discussion: This species, reported by Cushman (1937) from the Arkadelphia, was not identified from the samples studied by the writer. The holotype in the USNM was examined. Some specimens of *Gaudryina navarroana* Cushman are strongly compressed above the juvenarium and resemble immature individuals of *Clavulinoides compressus* (Cushman). These specimens are clearly biserial, however, and should not be confused with this species (see pl. I, fig. 18).

Clavulinoides insignis (Plummer)

Pl. I, figs. 19, 20

Tritaxia tricarinata (Reuss). Carsey, 1926, Texas Bur. Econ. Geol., Univ. Texas, Bull. 2612, p. 27, pl. 6, figs. 4a, b (not *Textularia tricarinata* Reuss, 1844).
Clavulina insignis Plummer, 1931, Texas Bur. Econ. Geol., Univ. Texas, Bull. 3101, p. 138, pl. 8, figs. 1-4.
Clavulinoides insignis (Plummer). Cushman, 1937, Cushman Lab. Foram. Res., Spec. Pub. 7, p. 124, pl. 17, figs. 14-17.
Clavulinoides insignis (Plummer) Cushman. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 39, pl. 10, figs. 8-11. (synonymy).
Clavulinoides insignis (Plummer). Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 73, pl. 6, figs. 1a, b, 2a, b.

Diagnosis: Test free, triangular throughout; form of megalospheric test subparallel or slightly expanding, of microspheric test broadening rapidly toward apertural end; chambers distinct, in adult microspheric test low and broad and deeply concave, in adult megalospheric test somewhat higher and slightly concave, angles sharply keeled; sutures distinct, slightly depressed in the uniserial portion; wall agglutinated, finely arenaceous with much cement, smoothly finished; aperture terminal and trilobed with the lobes pointing toward the peripheral angles, with a slight neck in the megalospheric form.

Figured specimens: USNM 639451, microspheric (fig. 19); USNM 639452, megalospheric (fig. 20), length 1.15 mm, breadth 0.54 mm, collected 9 feet above the base. Compared with numerous identified specimens in USNM: compare favorably.

Discussion: This species is common in the upper Navarro of Texas and equivalents in Arkansas, Alabama, and Mississippi. It is evidently derived from forms such as *C. trilaterus concavus* (Cushman) from the Taylor group (Cushman, 1946, p. 40). *C. insignis* (Plummer) is characterized by the strong peripheral keels and the sharp distinction between the juvenarium and the adult chambers. The shape and size of the microspheric and megalospheric forms differ markedly.

Subfamily Valvulininae Berthelin, 1880

Genus Marssonella Cushman, 1933

Marssonella Cushman, 1933, Cushman Lab. Foram. Res., Contr., vol. 9, pt. 2, p. 36.

Type species: Gaudryina oxycona Reuss, 1860. Original designation. *Gender:* feminine.

Marssonella oxycona (Reuss)

Pl. I, fig. 21

Gaudryina oxycona Reuss, 1860, Akad. Wiss. Wien, Math.-naturw. Kl., Sitzb., vol. 40, p. 229, pl. 12, fig. 3a-c.
Marssonella oxycona (Reuss). Cushman, 1933, Cushman Lab. Foram. Res., Contr., vol. 9, pt. 2, p. 36, pl. 4, figs. 13a, b.
Marssonella oxycona (Reuss) Cushman. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 43, pl. 12, figs. 3-5. (synonymy, *partim*).
Marssonella oxycona (Reuss). Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 75, pl. 6, figs. 17a, b.

Diagnosis: Test conical, gradually tapering or broadly flaring; earliest whorl with four or five chambers, later reduced to three, then two in the adult, rounded in transverse section; chambers distinct, not inflated, simple; sutures distinct, normally flush with the exterior surface; wall agglutinated, coarsely or finely arenaceous with larger quartz grains at the surface, smoothly finished or slightly roughened; aperture a broad, low opening at the inner margin of the last-formed chamber with a valvular, toothlike median projection.

Figured specimen: USNM 639453, length 0.65 mm, maximum diameter 0.432 mm, collected 8 feet below the top. Compared with numerous identified specimens in USNM: compares favorably, but smaller.

Discussion: This species is characteristic of the upper Cretaceous of Europe and is reported from the lower Cretaceous Gault. In North America it ranges from the Austin through Navarro groups and is widely distributed in the Gulf Coast. It also is reported from the Navesink marl and Mt. Laurel sand of New Jersey and the Mal Paso shale of Peru.

Genus Dorothia Plummer, 1931

Dorothia Plummer, 1931, Texas Bur. Econ. Geol., Univ. Texas, Bull. 3101, p. 130.

Type species: Gaudryina bulletta Carsey, 1926. Original designation. *Gender:* feminine.

Dorothia bulletta (Carsey)

Pl. I, fig. 22

Gaudryina bulletta Carsey, 1926, Texas Bur. Econ. Geol., Univ. Texas, Bull. 2612, p. 28, pl. 4, fig. 4.
Dorothia bulletta (Carsey). Plummer, 1931, Texas Bur. Econ. Geol., Univ. Texas, Bull. 3101, p. 132, pl. 8, figs. 13-17.
Dorothia bulletta (Carsey) Plummer. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 46, pl. 12, figs. 21-26. (synonymy).
Dorothia bulletta (Carsey). Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 75, pl. 6, figs. 19a, b.

Diagnosis: Test subcylindrical, base tapering or broadly rounded, sides subparallel, rounded in transverse section; juvenarium with five chambers to a volution, reducing to three and to two in the adult; chambers distinct, slightly inflated and overlapping in adult stage; sutures distinct, slightly depressed; wall agglutinated arenaceous with much cement, smoothly finished; aperture a low, broad opening at the inner margin of the last-formed chamber.

Figured specimen: USNM 639454, length 0.825 mm, maximum diameter 0.350 mm, collected 8 feet below the top. Compared with numerous identified specimens in USNM: compares favorably.

Discussion: This species is common in the Navarro and Taylor and equivalents of the Gulf Coast. It is reported also from South Dakota, Nebraska, New Jersey, Colombia, and the Georges Bank Canyons (Navarro age) in the Atlantic Ocean.

Dorothia conula (Reuss)

Pl. I, fig. 23

Textularia conulus Reuss, 1844, Geogn. Skizzen Böhmen, II: Die Kreidegebilde. . ., Prague: C. W. Medau, vol. 2, p. 215.
Textularia conulus Reuss. Reuss, 1845, Versteiner. böhm. Kreidefm., pt. 1, p. 38, pl. 8, fig. 59; pl. 13, fig. 75.
Dorothia conula (Reuss). Cushman, 1937, Cushman Lab. Foram. Res., Spec. Pub. 8, p. 76, pl. 8, figs. 11-17.
Dorothia conula (Reuss) Cushman. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 44, pl. 12, figs. 12-14. (synonymy).
Dorothia conulus (Reuss). Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 75, pl. 6, figs. 21a, b.

Diagnosis: Test short and stout, strongly tapering, rounded in section or somewhat compressed; juvenarium with five or six chambers to a volution, reducing to three and to two in the adult; adult chambers few in number, slightly inflated with slightly depressed, horizontal sutures; wall agglutinated, finely arenaceous, smoothly finished; aperture an elongate, low opening at the inner margin of the last-formed chamber.

Figured specimen: USNM 639455, length 0.90 mm, maximum diameter 0.450 mm, collected 8 feet below the top. Compared with numerous identified specimens in USNM: compares favorably.

Discussion: This species is characteristic of the Turonian of Europe and occurs in the lower Senonian (Cushman, 1946). It occurs in the Taylor and Navarro and equivalents in Arkansas and Texas.

Genus Plectina Marsson, 1878

Plectina Marsson, 1878, Naturw. Ver., Neu-Vorpommern u. Rügen, Greifswald, Mitt., Berlin, Jahrg. 10, p. 160.

Type species: Gaudryina ruthenica Reuss, 1851. Subsequent designation [Cushman, 1933, cited as *Plectina ruthenica* (Reuss)]. *Gender:* feminine.

?Plectina watersi Cushman

Plectina watersi Cushman, 1933, Cushman Lab. Foram. Res., Contr., vol. 9, pt. 3, p. 57, pl. 7, figs. 1a-d.
Plectina watersi Cushman. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 47, pl. 13, figs. 6, ?7-10, *not* 11, 12.
Plectina watersi Cushman. Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 76, pl. 6, figs. 25a, b.

Discussion: This species is stated to be characteristic of the Navarro beds (Cushman, 1946). However, there is some confusion regarding its precise identification. Cushman (1946) reports the species from

the Arkadelphia, but specimens which appear to agree with his descriptions do not agree with the holotype and paratypes of *Plectina watersi* Cushman in the USNM. Conversely, they are indistinguishable from two of the paratypes of *Goesella rugulosa* Cushman in the USNM which were collected from the Arkadelphia. A plastogamous (?) Arkadelphia specimen (see Plate II, fig. 2) has a clearly subterminal aperture and appears to agree with Cushman's interpretation of *Plectina watersi* Cushman.

Genus GOESELLA Cushman, 1933

Goësella CUSHMAN, 1933, Cushman Lab. Foram. Res., Contr., vol. 9, pt. 2, p. 34.

Type species: Clavulina rotundata Cushman, 1913. Original designation. *Gender:* feminine.

GOESELLA RUGULOSA Cushman

Pl. II, figs. 4, 5

Goësella rugulosa CUSHMAN, 1933, Cushman Lab. Foram. Res., Contr., vol. 9, pt. 3, p. 55, pl. 6, figs. 7a-d.

Goësella rugulosa Cushman. CUSHMAN, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 47, pl. 13, figs. 13a-d. (synonymy).

?, Plectina watersi Cushman. CUSHMAN, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 47, pl. 13, figs. 11, 12, *not* 6-10.

Goësella rugulosa Cushman. FRIZZELL, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 76, pl. 6, figs. 26a, b.

Diagnosis: Test elongate, juvenarium rapidly enlarging, adult portion subcylindrical; normally four chambers to a volution in the juvenarium, reducing to three, then two, and in the adult nearly uniserial; sutures slightly depressed, fairly distinct; wall agglutinated, arenaceous, juvenarium smoothly finished, adult chambers somewhat rougher; adult aperture terminal, rounded, without a neck.

Figured specimens: USNM 639456 (fig. 4), length 0.85 mm, diameter 0.40 mm; USNM 639457 (fig. 5); collected 8 feet below the top. Compared with the holotype in the USNM: agree.

USNM 639458 (fig. 1) and USNM 639459 (fig. 3) are identical to paratypes in the USNM of *G. rugulosa* Cushman from the Arkadelphia, but are more similar to Arkadelphia specimens referred by Cushman to *Plectina watersi* Cushman than to the holotype of *Goesella rugulosa* Cushman. They are identified here as *?Goesella rugulosa* Cushman.

Superfamily MILIOLACEA Ehrenberg, 1839

Family MILIOLIDAE Ehrenberg, 1839

Subfamily QUINQUELOCULININAE Cushman, 1917

Genus QUINQUELOCULINA d'Orbigny, 1826

Quinqueloculina D'ORBIGNY, 1826, Ann. Sci. Nat., sér. 1, tome 7, p. 301.

Type species: Serpula seminulum Linné, 1758. Subsequent designation, Parker and Jones, 1859 [cited as *Quinqueloculina seminulum* (Linné)]. *Gender:* feminine.

QUINQUELOCULINA sp.

Pl. II, fig. 6

Diagnosis: Test elongate; chambers distinct, somewhat rounded, apertural end projecting; sutures distinct, slightly depressed; wall porcellanous, smooth; aperture rounded, terminal.

Figured specimen: USNM 639460, length 0.550 mm, breadth 0.338 mm, collected 8 feet below the top.

Discussion: This form is rare in the Arkadelphia. It differs from *Quinqueloculina antiqua angusta* Franke, 1928, which has angular chambers and which is reported from the Taylor and Navarro of the Gulf Coast.

Superfamily NODOSARIACEA Ehrenberg, 1839

Family NODOSARIIDAE Ehrenberg, 1839

Subfamily LAGENINAE Reuss, 1862

Genus LAGENA Walker and Jacob, 1798

Lagena WALKER and BOYS, 1784, Testacea minuta rariora, nuperrime detecta in arena littoris Sandvicensis, J. March: London, p. 2 [Subgenus of *Serpula*].

Lagena WALKER and JACOB, 1798, *in* Kanmacher's ed. of Adams's Essays Micros., p. 634.

Type species: Serpula (Lagena) sulcata Walker and Jacob, 1798, = *Serpula (Lagena) striata sulcata rotunda* Walker and Boys, 1784. Subsequent designation, Parker and Jones, 1859 [cited as *Lagena sulcata* Walker and Jacob]. *Gender:* feminine.

LAGENA HISPIDA Reuss

Pl. IV, figs. 17, 18

Lagena hispida REUSS, 1858, Zeitschr. deutsch.

geol. Gesell., vol. 10, p. 434. [*nomen*].
Lagena hispida Reuss. Reuss, 1863, Akad. Wiss. Wien, Math.-naturw. Kl., Sitzb., vol. 46 (Jahrgang 1862), p. 335, pl. 6, figs. 77-79.
Lagena hispida Reuss. Brady, 1884, Challenger, Rept., Zoology, vol. 9, pp. 444, 459, pl. 57, figs. 1-4.
Lagena hispida Reuss. Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 102, pl. 14, fig. 8. (synonymy).
Lagena hispida Reuss. Barker, 1960, Soc. Econ. Paleo. Mineral, Spec. Pub. 9, p. 116, pl. 57, figs. 1-4.

Diagnosis: Test small, varied, surface finely spinose; wall calcareous, perforate; apertural end produced, forming an elongate, slender neck, with a delicate spine at the base of the single chamber in some specimens; aperture terminal, radiate.

Figured specimens: USNM 639461 (fig. 17), length 0.25 mm, diameter 0.175 mm; USNM 639462 (fig. 18); collected 8 feet below the top. Compared with numerous plesiotypes in USNM: compare favorably.

Discussion: This form is rare in the Arkadelphia. It has been reported from the Austin, Taylor, Navarro, and Midway groups of Texas, Arkansas, Mississippi, and Tennessee.

Lagena sulcata (Walker and Jacob)

Serpula (Lagena) striata sulcata rotunda Walker and Boys, 1784, Testacea minuta rariora, p. 2, pl. 1, fig. 6.
Serpula (Lagena) sulcata Walker and Jacob, 1798, *in* Kanmacher's ed. of Adams's Essays Micros., p. 634, pl. 14, fig. 5.
Lagena sulcata (Walker and Jacob). Carsey, 1926, Texas Bur. Econ. Geol., Univ. Texas, Bull. 2612, p. 31, pl. 7, fig. 4.
Lagena sulcata (Walker and Jacob). Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 103, pl. 14, fig. 14. (synonymy).

Lagena sulcata semiinterrupta Berry

Pl. IV, fig. 19

Lagena sulcata (Walker and Jacob) var. *semiinterupta* W. Berry, 1929, *in* Berry and Kelley, U. S. Nat. Mus. Proc., vol. 76, art. 19, p. 5, pl. 3, fig. 19.
Lagena sulcata (Walker and Jacob), var. *semiinterrupta* W. Berry. Cushman, 1931, Tennessee Div. Geol., Bull. 41, p. 37, pl. 5, figs. 9-11.
Lagena sulcata (Walker and Jacob) Parker and Jones var. *semiinterrupta* W. Berry. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 94, pl. 39, figs. 18-21. (synonymy).

Diagnosis: Test small, flask-shaped, surface ornamented with 16 or 18 plate-like costae arranged in pairs which join near the apical end and appear looped; wall calcareous, perforate; apertural end produced into a slender neck; aperture rounded, terminal.

Figured specimen: USNM 639463, length 0.20 mm, maximum diameter 0.125 mm, collected 9 feet below the top. Compared with the holotype in USNM: agrees favorably.

Discussion: This subspecies differs from the typical form in the character of the paired costae which appear to form loops near the apical end. It is reported from the uppermost Cretaceous of Tennessee and New Jersey.

Subfamily Nodosariinae Ehrenberg, 1839

Genus Lenticulina Lamarck, 1804

Lenticulina Lamarck, 1804, Mus. Natl. d'Hist. Nat., Ann., vol. 5, p. 186.

Type species: Lenticulites rotulata Lamarck, 1804. Subsequent designation, Cushman, 1927. *Gender:* feminine.

Discussion: Lenticulina Lamarck cannot be separated satisfactorily from *Robulus* Montfort, *Astacolus* Montfort, *Cristellaria* Lamarck, and related forms designated as genera by various authors. Some species of *Lenticulina* Lamarck appear to grade into *Saracenaria* Defrance, *Marginulina* d'Orbigny, and other related genera.

Subgenus Lenticulina Lamarck, 1804

Lenticulina (Lenticulina) rotulata (Lamarck)

Pl. II, fig. 16

Lenticulites rotulata Lamarck, 1804, Mus. Natl. d'Hist. Nat., Ann., vol. 5, p. 188; vol. 8 (1806), pl. 62 (14), fig. 11.
Cristellaria rotulata Lamarck. Carsey, 1926, Texas Bur. Econ. Geol., Univ. Texas, Bull. 2612, p. 39, pl. 6, fig. 2.
Lenticulina rotulata (Lamarck). Plummer, 1931, Texas Bur. Econ. Geol., Univ. Texas, Bull. 3101, p. 142, pl. 11, fig. 20.
"*Lenticulina rotulata* (Lamarck)". Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 82, pl. 8, fig. 14. (synonymy).

Diagnosis: Test involute, biconvex; peripheral margin sharply angular with a distinct keel; 8 to 9 chambers in the adult volution; sutures distinct, slightly raised, tangential at the umbo from which they radiate as slightly curved lines; umbo distinct; apertures of earlier chambers visible at the periphery; radiate aperture slightly raised at the extremity of the last-formed chamber.

Figured specimen: USNM 639464, maximum diameter 0.80 mm, collected 8 feet below the top. Compared with numerous plesiotypes in USNM: agrees favorably with forms from the Western Hemisphere identified as *L. rotulata* Lamarck.

Discussion: Many forms referred to Lamarck's species are not conspecific. "*Lenticulina rotulata* (Lamarck)" is quite variable even within the Gulf Coast Cretaceous. The practice of assigning specimens with a distinct umbo, a distinct keel, and slightly curved tangential sutures to this species is followed here.

Lenticulina (Lenticulina) jonesi Sandidge

Lenticulina jonesi Sandidge, 1932, Jour. Paleontology, vol. 6, p. 273, pl. 42, figs. 1, 2.
Lenticulina jonesi Sandidge. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 55, pl. 18, fig. 14. (synonymy).
Lenticulina jonesi Sandidge. Cushman, 1949, U. S. Geol. Surv., Prof. Paper 221-A, p. 4, pl. 2, fig. 4.

Discussion: This species, reported by Cushman (1949) from the Arkadelphia, was not identified from the samples studied by the writer.

Subgenus Robulus Montfort, 1808

Robulus Montfort, 1808, Conch. Syst., vol. 1, p. 215, 54th genre.

Type species: Robulus cultratus Denys de Montfort, 1808. Original designation. *Gender:* masculine.

Discussion: This subgenus differs from the typical subgenus principally in the character of the radiate aperture, which has an enlarged slit extending into the apertural face along the median line.

Lenticulina (Robulus) navarroensis (Plummer)

Pl. II, fig. 11

Cristellaria cultrata Montfort. Carsey (*not* Montfort), 1926, Texas Bur. Econ. Geol., Univ. Texas, Bull. 2612, p. 38, pl. 6, fig. 3.
Cristellaria navarroensis Plummer, 1927, Texas Bur. Econ. Geol., Univ. Texas, Bull. 2644, p. 39, text figs. 4a, b.
Cristellaria midwayensis Plummer. Berry and Kelley (*not* Plummer), 1929, U. S. Natl. Mus., Proc., vol. 76, art. 19, p. 7, pl. 1, fig. 3.
Lenticulina navarroensis (Plummer). Plummer, 1931, Texas Bur. Econ. Geol., Univ. Texas, Bull. 3101, p. 141.
Robulus navarroensis (Plummer). Jennings, 1936, Bull. Amer. Paleontology, vol. 23, no. 78, p. 15, pl. 1, figs. 14a, b.
Robulus navarroensis (Plummer) Cushman [sic]. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 51, pl. 16, figs. 6-8. (synonymy).
Robulus navarroensis (Plummer) var. *navarroensis* (Plummer). Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 81, pl. 8, fig. 6.

Diagnosis: Test closely coiled; umbonate, the sutures distinctly limbate and fused with the umbo which is slightly raised; periphery bears a prominent, thin keel; chambers 10 to 12 in the adult volution, quite distinct, gradually increasing in size; sutures quite distinct, limbate, curved; wall smooth and flush except near the umbo; aperture radiate with an enlarged ventral slit in the median line.

Figured specimen: USNM 639465, maximum diameter 0.913 mm, collected 16 feet above the base. Compared with plesiotypes in USNM: agrees, though smaller than some plesiotypes.

Discussion: This species, as the name implies, is characteristic of the Navarro. It is abundant in the Arkadelphia and equivalent strata. The species displays considerable individual variation, a common feature of this subgenus. It is reported from Texas, Arkansas, Mississippi, Alabama, New Jersey, Kansas, Nebraska, and South Dakota.

Lenticulina (Robulus) navarroensis extruatus (Cushman)

Pl. II, fig. 12

Robulus navarroensis (Plummer) var. *extruatus* Cushman, 1941, Cushman Lab. Foram. Res., Contr., vol. 14, pt. 2, p. 31, pl. 5, fig. 1.
Robulus navarroensis (Plummer) Cushman var. *extruatus* Cushman. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 52, pl. 16, figs. 9, 10; pl. 17, fig. 2. (synonymy).
Robulus navarroensis (Plummer) var. *extruatus* Cushman. Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 81, pl. 8, figs. 5a, b.

Diagnosis: Test exhibits a tendency to uncoil; sutures decidedly raised into thickened ridges instead of fusing into the smooth umbo as in the typical subspecies.

Figured specimen: USNM 639466, maximum diameter 1.25 mm, collected 8 feet below the top. Compared with the holotype and paratypes in USNM: agrees, but this specimen is smaller.

Discussion: Cushman states (1946): "This seems to be a varietal form of *R. navarroensis* and has a distinct keel. It also tends

toward *R. spisso-costatus* in its ornamentation and may be a stage between the two." This subspecies is abundant in the Arkadelphia. It is reported from the Corsicana marl and Kemp clay of Texas and the Prairie Bluff chalk of Mississippi.

Lenticulina (Robulus) pondi (Cushman)

Pl. II, fig. 13

Robulus pondi Cushman, 1931, Tennessee Div. Geol., Bull. 41, p. 25, pl. 2, figs. 9a, b.
Robulus pondi Cushman. Cushman, 1946, U. S. Geol., Surv., Prof. Paper 206, p. 52, pl. 16, figs. 1-5. (synonymy).
Robulus pondi Cushman. Cushman, 1949, U. S. Geol. Surv., Prof. Paper 221-A, p. 4, pl. 2, figs. 2, 3.
Robulus pondi Cushman. Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 81, pl. 8, figs. 7a, b.

Diagnosis: Test closely coiled, tending to uncoil in some specimens; umbos flattened; periphery angled, the apertures of earlier chambers forming prominent nodes between the straight to slightly concave chamber margins; chambers 10 to 12 in the adult volution, distinct, slightly enlarging as added; sutures distinct, subtangential, slightly curved; wall smooth; aperture radiate with an additional circular opening at the summit of the apertural face.

Figured specimen: USNM 639467, maximum diameter 0.975 mm, collected 8 feet below the top. Compared with the holotype and paratypes in USNM: smaller than holotype, nodes more prominent; agrees exactly with several paratypes from the Selma chalk.

Discussion: This species is common in beds of upper Taylor and Navarro age in Texas, Arkansas, Mississippi, Alabama, and Tennessee.

Lenticulina (Robulus) spissocostatus (Cushman)

Pl. II, fig. 14

Cristellaria pseudomamilligerus H. J. Plummer. Albritton and Phleger (*not* Plummer), 1937, Jour. Paleontology, vol. 11, no. 4, p. 351.
Robulus spisso-costatus Cushman, 1938, Cushman Lab. Foram. Res., Contr., vol. 14, pt. 2, p. 32, pl. 5, fig. 2.
Robulus spisso-costatus Cushman. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 52, pl. 16, figs. 11-14; pl. 17, figs. 1a, b. (synonymy).
Robulus spisso-costatus Cushman. Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 81, pl. 9, figs. 9a, b.

Diagnosis: Test compressed, the juvenarium closely coiled, the adult chambers slightly evolute exposing the inner portion of the penultimate coil; periphery subacute with a slight, rounded keel; chambers 9 to 12 in the adult volution, increasing gradually in size as added, uniformly shaped; sutures distinct, curved, limbate, raised, thickened near the umbo and fused with the umbo; wall smooth, except for the raised sutures; aperture radiate, placed at the outer angle, with a ventral supplementary slit in the median line.

Figured specimen: USNM 639468, maximum diameter 1.16 mm, collected 8 feet below the top. Compared with the holotype and paratypes in USNM: smaller than holotype; agrees exactly with several paratypes from the Corsicana marl.

Discussion: This species is characteristic of upper Navarro strata. It is reported from the Corsicana marl, the Kemp clay, the Prairie Bluff chalk, and the Selma chalk. It differs from *L.* (*R.*) *navarroensis* (Plummer) in the absence of a thin, flange-like keel and in the greatly thickened sutures near and at the umbo.

Lenticulina (Robulus) muensteri (Roemer)

Pl. II, fig. 15

Robulina münsteri Roemer, 1839, Versteiner. norddeutschen Oolithen-Gebirges, Nachtrag. (Hannover), p. 48, pl. 20, figs. 29a, b.
Cristellaria münsteri (Roemer). Reuss, 1863, Akad. Wiss. Wien, Math.-naturw. Kl., Sitzb., vol. 46, pt. 1, p. 77, pl. 9, figs. 3, 4.
Robulus münsteri (Reuss) (?). Cushman, 1932, Jour. Paleontology, vol. 6, no. 4, p. 334, pl. 50, figs. 2a, b.
Robulus münsteri (Roemer) Cushman. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 53, pl. 17, figs. 3-9. (synonymy).
Robulus münsteri (Roemer) Cushman. Cushman, 1949, U. S. Geol. Surv., Prof. Paper 221-A, p. 4.
Robulus münsteri (Roemer). Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 81, pl. 8, figs. 1a, 1b, 2-4.

Diagnosis: Test compressed, involute, except for the last few adult chambers of some specimens which are slightly evolute, exposing the penultimate coil; periphery with a sharp keel; strongly umbonate; chambers 9 to 12 in the adult volution, distinct, uniform, increasing gradually in size as added, not inflated; sutures distinct, tangential, slightly curved, slightly limbate; wall smooth; aperture radiate, positioned at the peripheral angle.

Figured specimen: USNM 639469, maximum diameter 1.00 mm, collected 8 feet below the top. Compared with plesiotypes in USNM: well within the range of forms from the Western Hemisphere identified as *R. münsteri* (Roemer); identical to some plesio-

types from the upper Taylor marl of Texas.

Discussion: There is wide variation among forms identified with Roemer's species. It is doubtful if all are conspecific. Similar forms are reported from the Austin, Taylor, and Navarro strata of Texas, Arkansas, Mississippi, and Tennessee.

Genus Darbyella Howe and Wallace, 1933

Darbyella Howe and Wallace, 1933, Louisiana Geol. Surv., Geol. Bull. 2, p. 23.

Type species: Darbyella danvillensis Howe and Wallace, 1933. Original designation. *Gender:* feminine.

Diagnosis: Test closely coiled throughout, juvenarium planispiral, adult chambers formed to one side of the earlier plane of coiling; wall calcareous, finely perforate; surface generally smooth; aperture radiate or with an elongate slit at the peripheral angle.

Discussion: Numerous species of *Darbyella* Howe and Wallace have a radiate or robuline aperture. The generic description is here emended to include such forms.

Darbyella sp.

Pl. III, figs. 1, 2

Diagnosis: Test involute, biconvex, closely coiled, planispiral in juvenarium, adult volution displaced to one side; periphery sharply angled; eight chambers in the last volution; sutures distinct, slightly curved, tangential, radiating from the quite prominent umbo; chambers distinct, glassy; aperture radiate with an elongate slit 0.05 mm below the apex of the apertural face.

Figured specimen: USNM 639470, maximum diameter 0.65 mm, collected 8 feet below the top of the Arkadelphia.

Discussion: Only a single specimen of this form was recovered. In view of the belief of some workers that *Darbyella* is not morphologically sound, the species is best left unnamed.

Genus Planularia Defrance, 1826

Planularia Defrance, 1826, Dict. Sci. Nat., vol. 41 (pin-plo), p. 244.

Type species: Peneroplis auris Defrance, 1824. Monotypic. *Gender:* feminine.

Discussion: Strongly flattened species are assigned to this genus readily, but less flattened forms appear to grade into other genera.

Planularia dissona (Plummer)

Pl. III, fig. 3

Cristellaria reniformis d'Orbigny. Carsey (*not* d'Orbigny), 1926, Texas Bur. Econ. Geol., Univ. Texas, Bull. 2612, p. 37, pl. 3, fig. 2.
Astacolus dissonus Plummer, 1931, Texas Bur. Econ. Geol., Univ. Texas, Bull. 3101, p. 145, pl. 11, figs. 17, 18; pl. 15, figs. 2-7.
Planularia dissona (Plummer). Cushman, 1941, Cushman Lab. Foram. Res., Contr., vol. 17, pt. 3, p. 68, pl. 16, figs. 15-19.
Planularia dissona (Plummer) Cushman. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 57, pl. 19, figs. 11-18. (synonymy).
Planularia planotrochiformis Hussey and McNulty, 1950, Jour. Paleontology, vol. 24, no. 4, p. 472, text figs. 1-9.
Planularia dissona (Plummer). Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 82, pl. 8, figs. 17a, 17b, 18, 19.

Diagnosis: Test strongly compressed, thickest at the umbo; juvenarium closely coiled, adult portion of the megalospheric test uncoiling; periphery with a thin keel in the earlier portion, subacute in the uncoiled portion; chambers distinct, increasing rapidly in size as added, becoming elongate in the adult, somewhat inflated in the uncoiled portion of the test; sutures distinct, slightly limbate and curved in the earlier portion, slightly depressed and less strongly curved in the later uncoiled portion; wall smooth or with a few weak costae which are parallel to the periphery; aperture radiate, slightly raised, positioned at the peripheral angle.

Figured specimen: USNM 639471, length 0.79 mm, breadth 0.50 mm, collected 22 feet above the base. Compared with plesiotypes in USNM: well within the range of variation.

Discussion: This species is quite varied, but is an excellent marker for the upper Navarro. It has been reported from the Kemp clay, the Corsicana marl, and the Nacatoch sand.

Planularia deadericki Cushman

Pl. III, fig. 4

Planularia deadericki Cushman, 1947, Cushman Lab. Foram Res., Contr., vol. 23, pt. 3, p. 56, pl. 13, figs. 11-13.
Planularia deadericki Cushman. Cushman, 1949, U. S. Geol. Surv., Prof. Paper 221-A, p. 4, pl. 2, figs. 6, 7.

Diagnosis: Test strongly compressed, juvenarium closely coiled, later portion tending to uncoil; periphery carinate with a narrow, transparent keel; chambers distinct, only slightly inflated; sutures distinct, slightly depressed; wall ornamented with longitudinal costae, curved, similar to the periphery; aperture terminal, radiate, positioned at the peripheral angle.

Figured specimen: USNM 639472, length 0.60 mm, breadth 0.34 mm, collected 8 feet below the top. Compared with the holotype and paratypes in USNM: agrees.

Discussion: This species is more compressed and more ornate than *Planularia dissona* (Plummer). It is common in the Arkadelphia, but has not been reported from other strata.

Genus Marginulina d'Orbigny, 1826

Marginulina d'Orbigny, 1826, Ann. Sci. Nat., vol. 7, p. 258.

Type species: Nautilus raphanus Linné, 1758. Subsequent designation, Deshayes, 1832 [cited as *Marginulina raphanus* (Linné)]. *Gender:* feminine.

Marginulina sp.

Pl. III, fig. 5

Diagnosis: Test compressed; juvenarium coiled, later portion uncoiled; periphery strongly convex; venter of adult concave; chambers distinct, increasing gradually in size as added; sutures distinct, slightly curved; wall smooth; aperture radiate, positioned at the peripheral angle.

Figured specimen: USNM 639473, length 0.55 mm, breadth 0.30 mm, collected 9 feet above the base.

Discussion: This form resembles *Marginulina cretacea* Cushman, but the holotype and numerous paratypes of that species were examined and the Arkadelphia form is different in possessing a clearly defined reentrant between the juvenarium and the adult chambers. It differs from *M. curvatura* Cushman in being compressed.

Marginulina navarroana Cushman

Marginulina navarroana Cushman, 1937, Cushman Lab. Foram. Res., Contr., vol. 13, pt. 4, p. 98, pl. 14, figs. 17, 18.
Marginulina navarroana Cushman. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 62, pl. 22, figs. 1-5.
Marginulina navarroana Cushman. Cushman, 1949, U. S. Geol. Surv., Prof. Paper 221-A, p. 5, pl. 2, fig. 10.
Marginulina navarroana Cushman. Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 84, pl. 9, figs. 6-8.

Discussion: This species, reported by Cushman (1949) from the Arkadelphia, was not identified from the samples studied by the writer.

Marginulina silicula (Plummer)

Vaginulina (?) *trilobata* (d'Orbigny) (?). Cushman, 1930, Cushman Lab. Foram. Res., Contr., vol. 6, pt. 2, p. 30, pl. 4, fig. 11.
Hemicristellaria silicula Plummer, 1931, Texas Bur. Econ. Geol., Univ. Texas, Bull. 3101, p. 148, pl. 10, figs. 8, 9.
Marginulina silicula (Plummer). Cushman, 1937, Cushman Lab. Foram Res., Contr., vol. 13, pt. 4, p. 97, pl. 14, figs. 19-22.
Marginulina silicula (Plummer) Cushman. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 62, pl. 21, figs. 42-45. (synonymy).
Marginulina silicula (Plummer) Cushman. Cushman, 1949, U. S. Geol. Surv., Prof. Paper 221-A, p. 5, pl. 2, fig. 11.
Marginulina silicula (Plummer). Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 85, pl. 9, figs. 14, 15.

Discussion: This species, reported by Cushman (1949) from the Arkadelphia, was not identified from the samples studied by the writer.

Marginulina plummerae Cushman

Pl. III, fig. 6

Cristellaria lineara Carsey (not *C. linearis* d'Orbigny), 1926, Texas Bur. Econ. Geol., Univ. Texas, Bull, 2612, p. 36, pl. 2, fig. 3.
Hemicristellaria ensis (Reuss). Plummer (*not* Reuss), 1931, Texas Bur. Econ. Geol., Univ. Texas, Bull. 3101, p. 146, pl. 10, figs. 1-4.
Marginulina plummerae Cushman, 1937, Cushman Lab. Foram. Res., Contr., vol. 13, pt. 4, p. 97, pl. 13, figs. 21-23.
Marginulina plummerae Cushman. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 62, pl. 22, figs. 6-10. (synonymy).

Diagnosis: Test elongate, compressed, especially in the coiled juvenarium; adult portion of test uncoiled, less compressed, subcircular in transverse section; venter nearly straight, periphery slightly convex, becoming slightly concave in elongate specimens; chambers distinct, increasing rapidly in size in coiled portion, gradually in uncoiled portion and distinctly inflated; sutures distinct, limbate, gently curved, slightly raised, thickened at the middle; wall smooth except for the raised sutures; aperture radiate, positioned at the peripheral angle.

Figured specimen: USNM 639474, length 0.52 mm, breadth of adult portion 0.175 mm, collected 8 feet below the top. Compared with the holotype and paratypes in USNM: does not agree exactly with holotype, but is within the range of paratypes.

Discussion: This species is restricted to the upper Navarro strata. It is reported from the Kemp clay, the Corsicana marl, and the Prairie Bluff chalk.

Marginulina curvatura Cushman

Pl. III, fig. 7

Marginulina curvatura Cushman, 1938, Cushman Lab. Foram. Res., Contr., vol. 14, pt. 2, p. 34, pl. 5, figs. 13, 14.
Marginulina curvatura Cushman. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 63, pl. 22, figs. 11-14. (synonymy).
Marginulina curvatura Cushman. Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 84, pl. 8, figs. 40, 41.

Diagnosis: Test elongate, slightly compressed; juvenarium coiled, later chambers uncoiled in a curved to rectilinear series; chambers distinct, gradually more inflated and less overlapped in later portion, subcircular in transverse section; early sutures slightly depressed, gradually becoming distinctly depressed; wall smooth; aperture radiate, positioned at the peripheral angle.

Figured specimen: USNM 639475, length 0.46 mm, breadth 0.25 mm, collected 21 feet above the base. Compared with the holotype and paratypes in USNM: not quite as straight as the holotype; agrees exactly with one paratype.

Discussion: This species is restricted to upper Navarro strata. It is reported also from the Corsicana marl of Texas.

Marginulina siliqua Cushman

Pl. III, fig. 8

Marginulina siliqua Cushman, 1938, Cushman Lab. Foram. Res., Contr., vol. 14, pt. 2, p. 34, pl. 5, figs. 15, 16.
Marginulina siliqua Cushman. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 63, pl. 22, figs. 15, 16.
Marginulina siliqua Cushman. Cushman, 1949, U. S. Geol. Surv., Prof. Paper 221-A, p. 5, pl. 2, fig. 14.
Marginulina siliqua Cushman. Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 85, pl. 9, figs. 16, 17.

Diagnosis: Test small, strongly compressed, peripheral margin subacute; juvenarium coiled, adult chambers uncoiled; chambers distinct, short but increasing in breadth as added; the first four or five chambers extend back to the proloculus, later chambers form a gently curved linear series, latest chambers slightly inflated; sutures distinct, slightly limbate, faintly depressed between the last 2 or 3 adult chambers; wall smooth; aperture radiate, slightly projecting, positioned on the dorsal periphery.

Figured specimen: USNM 639476, length 0.32 mm, breadth 0.16 mm, collected 8 feet below the top. Compared with the holotype and paratype in USNM: agrees, though immature.

Discussion: This form is very rare in the Arkadelphia. It has been reported from the Kemp clay and the Corsicana marl of Texas.

Genus Dentalina d'Orbigny, 1826

Dentalina d'Orbigny, *in* Risso, 1826, Hist. Nat. l'Europe Méridionale, tome 4, p. 16.

Type species: Nodosaria (Dentaline) cuvieri d'Orbigny, 1826. Monotypic *in* Risso, 1826 [cited as *Dentalina cuvieri* (d'Orbigny)]. *Gender:* feminine.

Dentalina legumen (Reuss)

Pl. III, fig. 9

Nodosaria (Dentalina) legumen Reuss, 1845, Versteiner. böhm. Kreidefm., pt. 1, p. 28, pl. 13, figs. 23, 24.
Dentalina legumen (Reuss). Reuss, 1851, Haidinger's naturw. Abh., vol. 4, p. 10, pl. 1, fig. 14.
Dentalina nana (Reuss). Cushman (not *Nodosaria (D.) nana* Reuss, 1863; not *Nodosaria nana* Reuss, 1860), 1931, Tennessee Div. Geol., Bull. 41, p. 29, pl. 3, fig. 21.
Dentalina legumen Reuss. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 65, pl. 23, figs. 1, 2. (synonymy).
Dentalina legumen (Reuss). Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 88, pl. 9, figs. 56, 57.

Diagnosis: Test elongate, tapering, base pointed; chambers increase rapidly in size as added; sutures distinct, oblique, depressed; wall smooth; aperture radiate, terminal, peripherally positioned.

Figured specimen: USNM 639477, length 0.675 mm, collected 21 feet above the base. Compared with numerous plesiotypes in USNM: identical to the plesiotype from the Arkadelphia, agrees with others.

Discussion: This form is widely distributed through the upper Cretaceous strata of the Gulf Coast. It is of little value for correlation due to the variation in size, length, and shape of individuals.

Dentalina gracilis (d'Orbigny)

Pl. III, figs. 10, 11

Nodosaria (Dentalina) gracilis d'Orbigny, 1840, Soc. Géol. France, Mém., sér. 1, vol. 4, pt. 1, p. 14, pl. 1, fig. 5.
Dentalina gracilis (d'Orbigny). Franke, 1928, K. Preuss. Geol. Landesanstalt, Abh., new ser., vol. 111, p. 29, pl. 2, fig. 22.
Dentalina gracilis D'Orbigny. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 65, pl. 23, figs. 3-6. (synonymy).

Dentalina gracilis (d'Orbigny). FRIZZELL, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 88, pl. 9, figs. 49, 50.

Diagnosis: Test elongate, slender, slightly curved, tapering; initial portion blunt; chambers fairly uniform, increasing gradually in length and diameter as added; sutures distinct, strongly depressed; wall smooth; aperture radiate, terminal.

Figured specimens: USNM 639478 (fig. 10), length 1.00 mm, maximum diameter 0.175 mm, collected 8 feet below the top; USNM 639479 (fig. 11). Compared with plesiotypes in USNM: agree with plesiotypes from the Arkadelphia and other formations.

Discussion: This varied form is widely distributed in the upper Cretaceous of the Gulf Coastal Plain.

DENTALINA LORNEIANA d'Orbigny

Pl. III, figs. 12, 13

Dentalina lorneiana D'ORBIGNY, 1840, Soc. Géol. France, Mém., sér. 1, vol. 4, p. 14, pl. 1, figs. 8, 9.
Nodosaria lorneiana (d'Orbigny). REUSS, 1845, Versteiner. böhm. Kreidefm., pt. 1, p. 27, pl. 8, fig. 5.
Dentalina lorneiana D'Orbigny. CUSHMAN, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 66, pl. 23, figs. 7-11. (synonymy).
Dentalina lorneiana d'Orbigny. CUSHMAN, 1949, U. S. Geol. Surv., Prof. Paper 221-A, p. 5, pl. 2, fig. 16.
Dentalina lorneiana d'Orbigny. FRIZZELL, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 89, pl. 9, figs. 58, 59.

Diagnosis: Test elongate, slender, very slightly curved; initial portion broadly rounded; chambers increasing rapidly in length, but only gradually in diameter as added, slightly inflated; sutures distinct, slightly depressed; wall smooth; aperture radiate, terminal.

Figured specimens: USNM 639480 (fig. 13), length 0.80 mm, diameter 0.125 mm, collected 8 feet below the top; USNM 639481 (fig. 12). Compared with identified specimens in USNM: within the range of specimens, identical to some.

Discussion: This form is widely distributed in the Gulf Coast. It has been reported from the Austin, Taylor, and Navarro strata of Texas, Arkansas, Mississippi, and Tennessee and from the Niobrara chalk of Nebraska.

DENTALINA ACULEATA (d'Orbigny)

Pl. III, fig. 14

[?] *Nodosaria (Dentalina) aculeata* D'ORBIGNY, 1840, Soc. Géol. France, Mém., sér. 1, vol. 4, p. 13, pl. 1, figs. 2, 3 [possibly = *Ramulina*].
Lagena incidenta CARSEY, 1926, Texas Bur. Econ. Geol., Univ. Texas, Bull. 2612, p. 30, pl. 4, fig. 12.
Ramulina globulifera H. B. Brady. PLUMMER (*partim;* not *R. globulifera* Brady), 1931, Texas Bur. Econ. Geol., Univ. Texas, Bull. 3101, p. 174, pl. 11, fig. 15a (*not* 15b).
Dentalina aculeata d'Orbigny. CUSHMAN, 1944, Cushman Lab. Foram. Res., Contr., vol. 20, pt. 1, p. 6, pl. 2, fig. 11.
Dentalina aculeata (d'Orbigny). CUSHMAN *(partim),* 1946, U. S. Geol. Surv., Prof. Paper 206, p. 67, pl. 26, fig. 17 (*not* 18). (synonymy).
Dentalina aculeata (d'Orbigny) ?. FRIZZELL, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 86, pl. 9, fig. 27.

Diagnosis: Test free; chambers inflated, subpyriform, separated by strongly constricted, tubular necks; entire surface ornamented with numerous and irregular spines; aperture terminal, rarely preserved.

Figured specimen: USNM 639482, length of single chamber 0.75 mm, diameter 0.35 mm, collected 8 feet below the top. Compared with numerous identified specimens in USNM: agrees.

Discussion: This species was described by d'Orbigny from the Senonian of the Paris basin. His specimens may represent free terminal chambers of a *Ramulina* R. Jones. Forms identified with d'Orbigny's species are known only as separated, single chambers in the Cretaceous of North America.

DENTALINA CATENULA Reuss

Pl. III, figs. 15, 16

Dentalina catenula REUSS, 1860, Akad. Wiss. Wien, Math.-naturw. Kl., Sitzb., vol. 40, p. 185, pl. 3, fig. 6.
Nodosaria farcimen Soldani. CARSEY (not *Orthoceras farcimen* Soldani), 1926, Texas Bur. Econ. Geol., Univ. Texas, Bull. 2612, p. 34, pl. 4, fig. 11.
Dentalina soluta Reuss. PLUMMER (*not* Reuss), 1931, Texas Bur. Econ. Geol., Univ. Texas, Bull. 3101, p. 150, pl. 11, fig. 14.
Dentalina catenula Reuss. CUSHMAN, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 67, pl. 23, figs. 27-32. (synonymy).
Dentalina catenula Reuss. FRIZZELL, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 87, pl. 9, figs. 35-37.

Diagnosis: Test elongate, slightly curved, tapering; initial portion with a distinct spine; chambers pyriform, overlapping, increasing gradually in size as added, uniformly shaped, with the maximum diameter below the middle of the test and tapering toward the aperture; sutures distinct, strongly depressed; wall smooth; aperture radiate, terminal.

Figured specimens: USNM 639483 (fig. 16), length 2.20 mm, diameter 0.34 mm, collected 10 feet below the top; USNM 639484 (fig. 15). Compared with numerous identified specimens in USNM: agree.

Discussion: This species is widely distributed in the Taylor group of the Gulf Coast, but occurs only sparsely in the Navarro beds of Texas and Arkansas.

Dentalina basiplanata Cushman

Pl. III, fig. 17

Dentalina annulata (Reuss). Cushman (*not* Reuss), 1931, Tennessee Div. Geol., Bull. 41, p. 28, pl. 3, fig. 3.
Dentalina megalopolitana Reuss. Cushman (*partim; not* Reuss), 1931, Jour. Paleontology, vol. 5, no. 4, p. 304, pl. 34, fig. 17.
Dentalina reussi Neugeboren. Plummer (*not* Neugeboren), 1931, Texas Bur. Econ. Geol., Univ. Texas, Bull. 3101, p. 151, pl. 11, fig. 5.
Dentalina gracilis d'Orbigny. Albritton and Phleger (not *Nodosaria (D.) gracilis* d'Orbigny), 1937, Jour. Paleontology, vol. 11, no. 4, p. 350.
Dentalina basiplanata Cushman, 1938, Cushman Lab. Foram. Res., Contr., vol. 14, pt. 2, p. 38, pl. 6, figs. 6-8.
Dentalina basiplanata Cushman. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 68, pl. 24, figs. 1-6. (synonymy).
Dentalina basiplanata Cushman. Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 86, pl. 9, figs. 32, 33.

Diagnosis: Test elongate, slightly tapering, slightly curved; microspheric juvenarium bears oblique costae indicating coiling, commonly slightly compressed; chambers distinct, adult chambers inflated, increasing in size and inflation as added; earlier chambers more strongly overlapping; sutures distinct, somewhat limbate; earlier sutures flush, oblique; later sutures depressed, horizontal; wall calcareous; surface smooth, except for earliest portion of the test; aperture radiate, terminal.

Figured specimen: USNM 639485, length 1.15 mm, diameter 0.20 mm, collected 16 feet above the base. Compared with the holotype and paratypes in USNM: agrees.

Discussion: This species is common and widely distributed in the Taylor and Navarro of Texas, Arkansas, Mississippi, Alabama, and Tennessee.

Dentalina crinita Plummer

Pl. III, fig. 18

Nodosaria consobrina d'Orbigny. Carsey (not *Dentalina consobrina* d'Orbigny), 1926, Texas Bur. Econ. Geol., Univ. Texas, Bull. 2612, p. 32, pl. 2, fig. 5.
Dentalina crinita Plummer, 1931, Texas Bur. Econ. Geol., Univ. Texas, Bull. 3101, p. 154, pl. 11, figs. 12, 13.
Dentalina crinita Plummer. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 69, pl. 24, figs. 29, 30. (synonymy).
Dentalina crinita Plummer. Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 87, pl. 9, fig. 42.

Diagnosis: Test quite elongate, slender, diameter nearly uniform throughout; chambers distinct; earlier chambers not inflated, overlapping; later chambers become gradually more inflated and less strongly overlapping; sutures distinct, slightly limbate, later ones depressed; wall calcareous; surface of juvenarium smooth, of adult test ornamented with irregular spinose projections arranged in a longitudinal linear pattern, appearing hirsute; aperture radiate, terminal, raised, eccentric.

Figured specimen: USNM 639486, length 1.79 mm, diameter 0.20 mm, collected 16 feet above the base. Compared with identified specimens in USNM: agrees.

Discussion: This species is reported from the Taylor and Navarro of Texas, Arkansas, Mississippi, and Tennessee.

Dentalina delicatula Cushman

Pl. III, fig. 19

Nodosaria obliqua Linnaeus. Carsey (not *Nautilus obliquus* L.), 1926, Texas Bur. Econ. Geol., Univ. Texas, Bull. 2612, p. 35, pl. 2, fig. 6.
Dentalina obliqua (Linné). Plummer (not *Nautilus obliquus* L.), 1931, Texas Bur. Econ. Geol., Univ. Texas, Bull. 3101, p. 153, pl. 11, fig. 6.
Dentalina delicatula Cushman, 1938, Cushman Lab. Foram. Res., Contr., vol. 14, pt. 2, p. 40, pl. 6, figs. 19, 20.
Dentalina delicatula Cushman. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 70, pl. 25, figs. 1-6. (synonymy).
Dentalina delicatula Cushman. Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 88, pl. 9, figs. 46, 47.

Diagnosis: Test elongate, slender, gently curved, slightly tapering with a distinct spine at the base; chambers distinct; earlier chambers not inflated, overlapping, increasing slightly in height as added; adult chambers inflated, with a lobulate periphery, somewhat pyriform; sutures distinct, limbate, later ones depressed; wall calcareous, surface ornamented with numerous (15 to 20) strong longitudinal costae, somewhat lower and more delicate on the final chambers, unreduced at the sutures; aperture radiate, terminal, elevated on a tapered neck.

Figured specimen: USNM 639487, length 1.55 mm, diameter 0.275 mm, collected 22 feet above the base. Compared with the holotype and paratypes in USNM: agrees

with the holotype, within the range of the varied paratypes.

Discussion: This species differs from *Dentalina alternata* (Jones) in having more delicate and thinner walls and in the greater number of costae. *Dentalina delicatula* Cushman is reported only from the Navarro strata of Texas and Arkansas.

Genus Nodosaria Lamarck, 1816

Nodosaria Lamarck, 1816, Tableau Encyclopédique et Méthodique (Paris), pt. 23, pp. 13, 14.

Type species: Nautilus radicula Linné, 1758. Subsequent designation, Children, 1823 [cited as *Nodosaria radicula* (Linné)]. *Gender:* feminine.

Nodosaria vertebralis (Batsch)

Pl. III, fig. 20

Nautilus (Orthoceras) vertebralis Batsch, 1791, Conch. des Seesandes, pp. 2, 5, pl. 2, figs. 6a, b.
Dentalina vertebralis (Batsch). Sherborn and Chapman, 1886, Royal Micros. Soc., Jour., ser. 2, vol. 6, p. 752, pl. 14, figs. 39a, b.
Nodosaria vertebralis Batsch. H. B. Brady, 1884, Challenger, Rept., Zoology, vol. 9, p. 514, pl. 63, fig. 35; pl. 64, figs. 11-14.
Nodosaria vertebralis (Batsch). Plummer, 1927, Texas Bur. Econ. Geol., Univ. Texas, Bull. 2644, p. 88, pl. 5, fig. 10. (synonymy).
Nodosaria vertebralis (Batsch). Nuttall, 1930, Jour. Paleontology, vol. 4, no. 3, p. 283.
Nodosaria vertebralis (Batsch). Harris and Jobe, 1951, Microfauna of Basal Midway (Norman, Oklahoma), p. 23, pl. 4, fig. 9.

Diagnosis: Test elongate, slender, straight to slightly arcuate; chambers short, compact, subcylindrical; sutures marked by darker bands, constricted only between the last few chambers; wall calcareous; surface ornamented by a few (about 8) coarse, longitudinal costae; aperture radiate, somewhat eccentric, elevated on a neck.

Figured specimen: USNM 639488, length 2.75 mm, maximum diameter 0.41 mm, collected 22 feet above the base. Compared with numerous identified specimens in USNM: agrees.

Discussion: Individuals referred to *Nodosaria vertebralis* (Batsch) pass through intermediate forms with almost imperceptible gradation into *Nodosaria affinis* d'Orbigny and may be separated only with difficulty. This species is known from the Midway formation (Paleocene) of Arkansas and Texas. This is the first record from the uppermost Cretaceous of the Gulf Coast.

Nodosaria affinis Reuss

Pl. III, figs. 21, 22

Nodosaria (Dentalina) affinis Reuss, 1845, Versteiner. böhm. Kreidefm., pt. 1, p. 26, pl. 13, fig. 16.
Nodosaria vertebralis Batsch var. *austinensis* Carsey, 1926, Texas Bur. Econ. Geol., Univ. Texas, Bull. 2612, p. 31, pl. 7, fig. 12.
Nodosaria marla Carsey, 1926, Texas Bur. Econ. Geol., Univ. Texas, Bull. 2612, p. 34, pl. 4, fig. 6.
Nodosaria proxima Silvestri. Berry and Kelley (*not* Silvestri), 1929, U. S. Natl. Mus., Proc., vol. 76, art. 19, p. 7, pl. 1, fig. 13.
Nodosaria zippei Reuss. Plummer (*not* Reuss), 1931, Texas Bur. Econ. Geol., Univ. Texas, Bull. 3101, p. 157.
Nodosaria affinis Reuss. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 70, pl. 25, figs. 8-23. (synonymy).
Nodosaria affinis Reuss. Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 89, pl. 10, figs. 3-7.

Diagnosis: Test elongate, normally bearing a stout spine at the base; the microspheric form with many chambers, tapering, somewhat curved in some specimens, maximum width near the apertural end; the megalospheric form with a quite large proloculus, the few later chambers reducing rapidly in diameter; chambers distinct, inflated; sutures distinct, strongly compressed, somewhat limbate; wall calcareous; surface ornamented by numerous (about 13 to 15) longitudinal costae, sharp and platelike; aperture radiate, terminal, elevated on a neck.

Figured specimens: USNM 639489 (fig. 21), length 3.80 mm, maximum diameter 0.65 mm; USNM 639490 (fig. 22), length 1.00 mm; collected 22 feet above the base. Compared with numerous identified specimens in USNM: agree.

Discussion: This species is markedly dimorphic and somewhat variable, especially in the microspheric form. It is reported from numerous localities throughout the Austin, Taylor, and Navarro strata of Texas, Arkansas, Mississippi, Alabama, and Tennessee.

Nodosaria obscura Reuss

Pl. III, fig. 23

Nodosaria (Nodosaria) obscura Reuss, 1845, Versteiner. böhm. Kreidefm., pt. 1, p. 26, pl. 13, figs. 7-9.
Nodosaria obscura Reuss. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 73, pl. 26, figs. 15, 16. (synonymy).
Nodosaria obscura Reuss. Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 91, pl. 10, figs. 26, 27.

Diagnosis: Test fusiform, of varied lengths, broadest near the apertural end, pointed at the base; chambers obscured by the strong ornamentation of the test, not inflated; sutures indistinct, not depressed; wall calcareous; surface ornamented by 10 to 15 distinct, longitudinal costae extending the entire length of the test and coalescing and thickening at the apertural end to form a distinct, collar-like structure about the aperture; aperture obscurely radiate, terminal.

Figured specimen: USNM 639491, length 0.62 mm, diameter 0.14 mm, collected 8 feet below the top. Compared with numerous identified specimens in USNM: agrees.

Discussion: This species is more common in the upper Taylor and the Navarro strata of the Gulf Coast but also has been reported from the lower Selma (Austin age) of Mississippi.

Genus CHRYSALOGONIUM Schubert, 1907

Chrysalogonium SCHUBERT, 1907, Neues Jahr. für Min. Geol. Pal., vol. 25, p. 243.

Type species: Nodosaria polystoma Schwager, 1866. Original designation. *Gender:* neuter.

CHRYSALOGONIUM TEXANUM Cushman

Pl. III, fig. 24

Chrysalogonium texanum CUSHMAN, 1936, Cushman Lab. Foram. Res., Contr., vol. 12, pt. 3, p. 55, pl. 9, figs. 24, 25.
Chrysalogonium texanum Cushman. CUSHMAN, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 75, pl. 27, figs. 14, 15.
Chrysalogonium texanum Cushman. FRIZZELL, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 92, pl. 10, figs. 40, 41.

Diagnosis: Test quite elongate, slender, tapering, gently arcuate, a distinct spine at the base; chambers distinct, slightly inflated, increasing in length as added; length of adult chambers at least three times breadth; sutures distinct, slightly limbate, slightly depressed; wall calcareous; surface smooth; adult aperture sieve-like, slightly raised, terminal.

Figured specimen: USNM 639492, length 2.75 mm, maximum diameter 0.225 mm, collected 10 feet below the top. Compared with the holotype and paratypes in USNM: agrees, but larger.

Discussion: This species is reported from the Austin, Taylor, and Navarro of Texas and Arkansas.

CHRYSALOGONIUM GRANTI (Plummer)

Nodosaria filiformis d'Orbigny. CARSEY (*not* d'Orbigny), 1926, Texas Bur. Econ. Geol., Univ. Texas, Bull. 2612, p. 33, pl. 7, fig. 8.
Nodosaria granti PLUMMER, 1927, Texas Bur. Econ. Geol., Univ. Texas, Bull. 2644, p. 83, pl. 5, figs. 9a-d.
Dentalina granti (Plummer). PLUMMER, 1931, Texas Bur. Econ. Geol., Univ. Texas, Bull. 3101, p. 149, pl. 11, figs. 8, 9.
Ellipsonodosaria (?) *granti* (Plummer). CUSHMAN, 1936, Cushman Lab. Foram. Res., Contr., vol. 12, pt. 3, p. 51, pl. 9, figs. 3-5.
Ellipsonodosaria? granti (Plummer) Cushman. CUSHMAN, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 136, pl. 56, figs. 24-26. (synonymy).
Chrysalogonium granti (Plummer). FRIZZELL, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 92, pl. 10, fig. 21.

Discussion: This species, reported by Cushman (1949) from the Arkadelphia, was not identified from the samples studied by the writer.

Genus PSEUDONODOSARIA Boomgaart, 1949

Pseudonodosaria BOOMGAART, 1949, Smaller Foraminifera from Bodjonegoro (Java), Utrecht Univ., Thesis, p. 81.

Type species: Glandulina discreta Reuss, 1850. Original designation. *Gender:* feminine.

PSEUDONODOSARIA LARVA (Carsey)

Pl. IV, fig. 2

Nodosaria (Glandulina) manifesta (Reuss). CUSHMAN, 1926, Amer. Assoc. Petrol. Geol., Bull., vol. 10, no. 6, p. 594, pl. 18, fig. 8.
Nodosaria larva CARSEY, 1926, Texas Bur. Econ. Geol., Univ. Texas, Bull. 2612, p. 31, pl. 2, fig. 2.
Nodosaria radicula (Linnaeus). PLUMMER (not *Nautilus radicula* Linné, 1758), 1927, Texas Bur. Econ. Geol., Univ. Texas, Bull. 2644, p. 77, pl. 4, fig. 9a (*not* fig. 9b).
Nodosaria radicula (Linné). PLUMMER (not *Nautilus radicula* Linné), 1931, Texas Bur. Econ. Geol., Univ. Texas, Bull. 3101, p. 155, pl. 11 (fig. 1 ?), fig. 2.
Nodosaria humilis Roemer. CUSHMAN (*not* Roemer), 1931, Tennessee Div. Geol., Bull. 41, p. 32, pl. 4, fig. 5.
Pseudoglandulina manifesta (Reuss). CUSHMAN and TODD (not *Glandulina manifesta* Reuss, 1851), 1943, Cushman Lab. Foram. Res., Contr., vol. 19, pt. 3, p. 58, pl. 10, fig. 15.
Pseudoglandulina manifesta (Reuss). CUSHMAN (not *Glandulina manifesta* Reuss), 1946, U. S. Geol. Surv., Prof. Paper 206, p. 76, pl. 27, figs. 21-26 (*not* fig. 20).
Pseudoglandulina manifesta (Reuss). FRIZZELL (not *Glandulina manifesta* Reuss), 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 92, pl. 10, figs. 29, 31 (*not* fig. 30).

Diagnosis: "Test free, elongate, base smooth and rounded, consisting of a rectilinear series of

chambers, early ones closely appressed, strongly overlapping and subcylindrical, later chambers slightly inflated with a a lesser amount of overlap and separated by slight constrictions, final chamber turbinate in form, somewhat produced to the aperture; sutures distinct, straight, horizontal, flush with the surface in the early portion, slightly constricted in the later portion where the chambers are more inflated; wall calcareous, hyaline, surface smooth; aperture terminal, radiate. Specimens range from 0.39 to 0.88 mm in length and 0.18 to 0.26 mm in width." (Loeblich and Tappan, 1955).

Figured specimen: USNM 639493, length 0.475 mm, maximum diameter 0.20 mm, collected 8 feet below the top. Compared with numerous plesiotypes in USNM: agrees.

Genus Rectoglandulina Loeblich and Tappan, 1955

Rectoglandulina Loeblich and Tappan, 1955, Smithsonian Misc. Colln., vol. 126, no. 3, p. 3.

Type species: Rectoglandulina appressa Loeblich and Tappan, 1955. Original designation. *Gender:* feminine.

Rectoglandulina appressa Loeblich and Tappan

Pl. IV, fig. 1

Pseudoglandulina lagenoides (Olszewski). Cushman and Deaderick (not *Glandulina lagenoides* Olszewski, 1875), 1944, Jour. Paleontology, vol. 18, no. 4, p. 334, pl. 51, figs. 14, 15. [not *Pseudoglandulina lagenoides* (Olszewski). of Authors, *partim.*]

Pseudoglandulina sp. Plummer, 1931, Texas Bur. Econ. Geol., Univ. Texas, Bull. 3101, p. 158, pl. 10, figs. 16, 17.

Rectoglandulina appressa Loeblich and Tappan, 1955, Smithsonian Misc. Colln., vol. 126, no. 3, p. 4, pl. 1, figs. 1-4.

Diagnosis: "Test free, subfusiform, widest centrally, chambers uniserial, closely appressed, increasing rapidly in diameter from the pointed base, last chamber occupying one-half to three-fifths the length of the test, elongate turbinate in form; sutures distinct, horizontal, flush with the surface; wall calcareous, surface smooth; aperture terminal, radiate.

Length of holotype 0.44 mm, greatest breadth 0.23 mm. Other specimens range from 0.26 to 0.57 mm in length." (Loeblich and Tappan, 1955).

Figured specimen: USNM 639494, length 0.50 mm, maximum diameter 0.275 mm, collected 8 feet below the top.

Discussion: This species has been reported from the Ozan sand and the Annona chalk of Arkansas and from the Corsicana and Taylor marls of Texas.

Rectoglandulina lagenoides (Olszewski)

Pl. IV, fig. 3

Glandulina lagenoides Olszewski, 1875, Sprawozdonie Komisyi Fizyograficznéj, Akad. Umiejetnosci, Krakowie, vol. 9, p. 107, pl. 1, fig. 6.

[?] *Nodosaria laevigata* Nilsson. Carsey (*not* Nilsson), 1926, Texas Bur. Econ. Geol., Univ. Texas, Bull. 2612, p. 32, pl. 4, fig. 13.

Pseudoglandulina lagenoides (Olszewski). Cushman and Hedberg, 1941, Cushman Lab. Foram. Res., Contr., vol. 17, pt. 4, p. 89, pl. 21, fig. 34.

Pseudoglandulina lagenoides (Olszewski) Cushman and Hedberg. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 76, pl. 27, fig. 29. (synonymy, *partim*).

Pseudoglandulina lagenoides (Olszewski). Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 92, pl. 10, fig. 28.

Diagnosis: Test free, strongly fusiform, widest centrally, chambers uniserial, closely appressed; increasing rapidly in diameter from the pointed base to the midpoint of the test, then reducing in the last-formed chamber which forms about one-third the length of the test; sutures distinct, horizontal, flush with the surface; wall calcareous; surface smooth; aperture radiate, terminal.

Figured specimen: USNM 639495, length 0.60 mm, maximum breadth 0.21 mm, collected 10 feet below the top. Compared with numerous plesiotypes of *"Pseudoglandulina lagenoides* (Olszewski)" in USNM: agrees.

Discussion: This species differs from *Rectoglandulina appressa* Loeblich and Tappan in its more fusiform shape and in the ratio of the last-formed chamber to the length of the test. *R. lagenoides* (Olszewski) is known only from the upper Taylor and Navarro strata in the Gulf Coast.

Rectoglandulina pygmaea (Reuss)

Pl. IV, fig. 4

Glandulina pygmaea Reuss, 1851, Haidinger's naturw. Abh., vol. 4, pt. 1, p. 6, pl. 1, fig. 3.

Pseudoglandulina pygmaea (Reuss) Cushman. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 76, pl. 27, figs. 27, 28.

Pseudoglandulina pygmaea (Reuss). Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 92, pl. 10, fig. 37.

Diagnosis: Test free, small, fusiform; chambers strongly appressed, the last-formed chamber appearing to envelop the test; apertural end produced into a slight neck; sutures indistinct; wall calcareous; surface costate; aperture radiate, terminal.

Figured specimen: USNM 639496, length

0.35 mm, diameter 0.213 mm, collected 8 feet below the top. Compared with numerous plesiotypes in USNM: agrees.

Discussion: This form is reported from the Taylor and Navarro of Texas, Arkansas, Mississippi, and Alabama.

Genus SARACENARIA Defrance, 1824

Saracenaria DEFRANCE, 1824, Dict. Sci. Nat., vol. 32, p. 176.

Type species: Saracenaria italica Defrance, 1824. Monotypic. *Gender:* feminine.

SARACENARIA TRIANGULARIS (d'Orbigny)

Pl. IV, fig. 5

Cristellaria triangularis D'ORBIGNY, 1840, Soc. Géol. France, Mém., sér. 1, vol. 4, pt. 1, p. 27, pl. 2, figs. 21, 22.
Saracenaria triangularis (D'Orbigny). CUSHMAN and CHURCH, 1929, California Acad. Sci., Proc., ser. 4, vol. 18, p. 505, pl. 37, figs. 13, 14.
Saracenaria triangularis (D'Orbigny) Cushman and Church. CUSHMAN, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 58, pl. 28, figs. 1-3. (synonymy).
Saracenaria triangularis (d'Orbigny). FRIZZELL, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 83, pl. 8, figs. 28a, b.

Diagnosis: Test free, large; juvenarium coiled, the later chambers somewhat uncoiled, becoming triangular in transverse section; chambers distinct, few in number; sutures distinct, curved, not depressed; wall calcareous; surface smooth except for the thickened sides of the apertural face; aperture radiate, positioned at the peripheral angle.

Figured specimen: USNM 639497, length 0.425 mm, breadth 0.325 mm, collected 9 feet above the base. Compared with numerous plesiotypes in USNM: agrees favorably.

Discussion: This form is reported from the Austin, Taylor, and Navarro of Texas, Arkansas, Mississippi, Alabama, and Tennessee.

SARACENARIA SARATOGANA Howe and Wallace

Pl. IV, fig. 6

Saracenaria italica Defrance. CUSHMAN (*not* Defrance), 1931, Jour. Paleontology, vol. 5, no. 4, p. 305, pl. 34, figs. 15, 16.
Saracenaria cf. *italica* Defrance. CUSHMAN and TODD, 1943, Cushman Lab. Foram. Res., Contr., vol. 19, pt. 3, p. 58, pl. 10, fig. 17.
Saracenaria saratogana HOWE and WALLACE, 1932, Louisiana Dept. Conserv., Geol. Bull. 2, p. 41.
Saracenaria saratogana Howe and Wallace. CUSHMAN, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 58, pl. 28, figs. 4-6.
Saracenaria saratogana Howe and Wallace. FRIZZELL, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 83, pl. 8, figs. 20, 21.

Diagnosis: Test free; juvenarium coiled, adult chambers uncoiled, triangular in transverse section; adult chambers distinct, the angles bluntly rounded; sutures distinct, slightly curved, flush; wall calcareous, surface smooth except for the slightly projecting inner corners of the apertural faces of the uncoiled chambers; aperture radiate, slightly raised, positioned at the peripheral angle.

Figured specimen: USNM 639498, length 0.825 mm, breadth 0.35 mm, collected 9 feet above the base. Compared with numerous plesiotypes in USNM: within the range of specimens.

Discussion: This species is reported from the Navarro of Texas, Arkansas, Mississippi, and Alabama. It differs from *S. triangularis* (d'Orbigny) in the blunter angles and distinct uncoiling.

Genus VAGINULINA d'Orbigny, 1826

Vaginulina D'ORBIGNY, 1826, Ann. Sci. Nat., vol. 7, p. 257.

Type species: Nautilus legumen Linné, 1758. Subsequent designation, Cushman, 1913 [cited as *Vaginulina legumen* Linnaeus]. *Gender:* feminine.

VAGINULINA CRETACEA Plummer

Pl. IV, figs. 9, 10

Vaginulina gracilis var. *cretacea* PLUMMER, 1927, Texas Bur. Econ. Geol., Univ. Texas, Bull. 2644, p. 172, pl. 2, fig. 8.
Vaginulina cretacea Plummer. CUSHMAN, 1936, Geol. Soc. Amer., Bull., vol. 47, p. 417, pl. 1, fig. 5.
Vaginulina cretacea Plummer. CUSHMAN, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 80, pl. 30, figs. 11-14. (synonymy).
Vaginulina cretacea Plummer. FRIZZELL, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 93, pl. 10, figs. 54, 55.

Diagnosis: Test quite elongate, somewhat compressed, slender, tapering, slightly arcuate, peripheral edge concave, inner edge convex, periphery rounded; chambers numerous, distinct, inflated only slightly; juvenarium with slight traces of coiling; early chambers low, increasing gradually in height as added to the high and broad adult chambers; sutures quite distinct, slightly oblique in juvenarium, nearly horizontal in the adult, limbate with a raised, elongate beadlike protuberance at the midpoint of each suture; wall calcareous; surface smooth except for the raised sutures; aperture radiate, slightly produced, positioned at the peripheral angle.

Figured specimens: USNM 639499 (fig. 9), length 2.40 mm, width 0.50 mm; USNM 639500 (fig. 10), length 2.00 mm, collected 32 feet above the base. Compared with numerous plesiotypes in USNM: agree.

Discussion: This species is restricted to the Navarro of Texas, Arkansas, and Mississippi where it is common.

Genus Citharina d'Orbigny, 1839

Citharina d'Orbigny, *in* de la Sagra, 1839, Hist. Phys. Pol. Nat. Cuba, Foraminifères, p. 37.

Type species: Vaginulina (Citharina) strigillata Reuss, 1846. Subsequent designation, Loeblich and Tappan, 1949 [cited as *Citharina strigillata* Reuss, 1846]. *Gender*: *feminine.*

Citharina multicostata (Cushman)

Vaginulina multicostata Cushman, 1930, Cushman Lab. Foram. Res., Contr., vol. 6, pt. 2, p. 28, pl. 4, fig. 4.
Vaginulina simondsi Carsey. Cushman (*partim; not* Carsey), 1931, Tennessee Div. Geol., Bull. 41, p. 33, pl. 4, figs. 7a, b (*not* 8a, b).
Vaginulina simondsi Carsey. Cushman (*not* Carsey), 1931, Jour. Paleontology, vol. 5, no. 4, p. 306, pl. 35, fig. 7.
Vaginulina multicostata Cushman. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 79, pl. 29, figs. 9-16. (synonymy).
Citharina multicostata (Cushman). Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 95, pl. 11, figs. 27, 28.

Diagnosis: Test elongate, strongly compressed peripheral edge straight or gently curved, inner edge strongly convex, base pointed; chambers few, elongate, curved, low and broad, the last-formed extending halfway to the base along the inner margin; sutures distinct, somewhat limbate, not depressed, strongly oblique, gently curved; wall calcareous; surface ornamented with numerous fine costae subparallel to the peripheral edge; aperture radiate, elevated at the peripheral angle.

Identified specimen: USNM 639501 (not figured), length of broken specimen 1.25 mm, maximum breadth 0.25 mm, collected 15 feet below the top. Compared with the holotype (of which only the upper half remains) in USNM: agrees.

Discussion: This species is relatively rare in the Arkadelphia and only broken specimens were recovered from the samples studied. *C. multicostata* (Cushman) is reported from numerous localities in the Taylor and Navarro throughout the Gulf Coast province.

Citharina barcoensis (Cushman and Hedberg)

Pl. IV, fig. 7

Vaginulina barcoensis Cushman and Hedberg, 1941, Cushman Lab. Foram. Res., Contr., vol. 17, pt. 4, p. 90, pl. 22, fig. 2.

Diagnosis: Test strongly compressed, initial end acute, with a blunt spine, dorsal margin with a distinct keel and gently curved, ventral margin truncate, greatest breadth near the base; chambers distinct, not inflated, increasing gradually in height and rapidly in breadth as added, each reaching back toward the basal line; sutures distinct, curved, slightly limbate; wall calcareous; surface ornamented with fine, longitudinal costae subparallel to the dorsal margin; aperture terminal, slightly elevated, radiate.

Figured specimen: USNM 639502, length 1.05 mm, breadth 0.30 mm, collected 22 feet above the base.

Discussion: This species was described from the upper Cretaceous Colon formation, northeastern Colombia. It is distinguished by the carinate dorsal margin or keel and by the backward extension of the chambers to the basal line. It is rare in the Arkadelphia marl. The final chamber of the figured specimen extends backward about seven-eighths of the length of the test. It differs in this respect from *C. multicostata* (Cushman) in which the final chambers extend backward about halfway, and in greater breadth compared to the length of the test.

Vaginulina subplumoides Parr from the upper Eocene of Western Australia is similar but appears to lack the carinate dorsal margin. However, if examination of the actual specimen should reveal such a keel, Parr's name is prior and must be used for the American form.

Citharina simondsi (Carsey)

Pl. IV, fig. 8

Vaginulina simondsi Carsey, 1926, Texas Bur. Econ. Geol., Univ. Texas, Bull. 2612, p. 40, pl. 2, fig. 4.
Vaginulina simondsi Carsey. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 80, pl. 29, figs. 23-25. (synonymy).
Citharina simondsi (Carsey). Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 95, pl. 11, figs. 14, 15.

Diagnosis: Test free, of medium size, strongly compressed, broadest near the apertural end, peripheral and inner edges straight, thickened, strongly carinate, a distinct initial spine at the base; chambers numerous, distinct, low and

broad, increasing uniformly in breadth as added; sutures distinct, somewhat limbate, straight or only slightly curved, flush; wall calcareous; surface ornamented with longitudinal costae subparallel to the peripheral edge, generally stronger in the early stages; aperture radiate, elevated slightly at the peripheral angle.

Figured specimen: USNM 639503, length 1.54 mm, maximum breadth 0.375 mm, collected 10 feet below the top. Compared with numerous plesiotypes in USNM: compares favorably.

Discussion: This form is limited to the upper Navarro strata. It is rare in the Arkadelphia. It differs from the larger species *Citharina webbervillensis* (Carsey) in the more extensive costae present and in the nearly straight sutures.

Citharina navarroana (Cushman)

Vaginulina navarroana Cushman, 1936, Geol. Soc. Amer., Bull., vol. 47, p. 416, pl. 1, fig. 3.
Vaginulina navarroana Cushman. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 80, pl. 29, figs. 17-22. (synonymy).
Citharina navarroana (Cushman). Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 95, pl. 11, figs. 16-18.

Discussion: This species, reported by Cushman (1949) from the Arkadelphia, was not identified from the samples studied by the writer. The holotype of this small form (in the USNM) was examined.

Citharina webbervillensis (Carsey)

Pl. IV, fig. 11

Vaginulina webbervillensis Carsey, 1926, Texas Bur. Econ. Geol., Univ. Texas, Bull. 2612, p. 39, pl. 2, fig. 7.
Vaginulina webbervillensis Carsey. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 81, pl. 30, figs. 5-10. (synonymy).
Citharina webbervillensis (Carsey). Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 96, pl. 11, figs. 38, 39.

Diagnosis: Test quite large, strongly compressed, broadest near the apertural end, a distinct spine at the base, periphery of juvenarium bicarinate or tricarinate, periphery rounded and smooth in the adult, peripheral edge thickened and nearly straight, inner edge convex; chambers numerous, distinct, curved, low and broad, increasing rapidly in breadth as added; sutures distinct, limbate along the peripheral edge, flush, recurved toward the proloculus; wall calcareous; surface ornamented with a few costae, especially in the juvenarium; aperture radiate, produced, positioned at the peripheral angle.

Figured specimen: USNM 639504, length 3.075 mm, breadth 0.95 mm, collected 9 feet above the base. Compared with numerous plesiotypes in USNM: agrees.

Discussion: This is a large, easily recognized species characteristic of upper Navarro strata of the Gulf Coast province where it occurs in abundance.

Genus Neoflabellina Bartenstein, 1948

Neoflabellina Bartenstein, 1948, Senckenbergiana, vol. 28, no. 4-6, p. 122.

Type species: Flabellina rugosa d'Orbigny, 1840. Original designation. *Gender:* feminine.

Neoflabellina rugosa (d'Orbigny)

Pl. IV, fig. 12

Flabellina rugosa d'Orbigny, 1840, Soc. Géol. France, Mém., sér. 1, vol. 4, p. 23, pl. 2, figs. 4, 5, 7.
Flabellina interpunctata von der Marck, 1858, Naturh. Ver. Preuss. Rheinlande, Westfalens, Verh., vol. 15, p. 53, pl. 1, fig. 5.
Frondicularia baudouiniana (d'Orbigny). Cushman (*not* d'Orbigny), 1926, Cushman Lab. Foram. Res., Contr., vol. 2, pt. 1, p. 21, pl. 3, fig. 5.
not *Frondicularia projecta* Carsey, 1926, Texas Bur. Econ. Geol., Univ. Texas, Bull. 2612, p. 41, pl. 6, fig. 5.
not *Flabellina projecta* (Carsey). Plummer, 1931, Texas Bur. Econ. Geol., Univ. Texas, Bull. 3101, p. 165, pl. 12, figs. 5-8.
Palmula rugosa (d'Orbigny). Cushman, 1940, Foraminifera, Ed. 3, illus. key, p. 465, pl. 20, fig. 8.
Palmula rugosa (D'Orbigny) Cushman. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 83, pl. 31, figs. 9-17. (synonymy).
Neoflabellina rugosa (d'Orbigny). Bartenstein, 1948, Senckenbergiana, vol. 28, no. 4-6, p. 124.
Neoflabellina rugosa (d'Orbigny). Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 97, pl. 12, figs. 15, 16.

Diagnosis: Test free, sagittate to rhomboid or broadly elliptical in lateral view, strongly compressed, periphery truncated, sides nearly flat; microspheric juvenarium planispirally coiled; adult chambers chevron-shaped, narrow and embracing, extending back on either side and almost enclosing the juvenarium; sutures distinct, raised, sharp, and forming a loop near the apertural end of the last-formed chambers; wall calcareous; surface with small, raised papillae between the raised sutures; aperture indistinctly radiate, elevated on a short projecting neck.

Figured specimen: USNM 639505 (immature individual), length 0.475 mm, maximum breadth 0.325 mm, collected 32 feet above the base. Compared with numerous

plesiotypes in USNM: compares favorably.

Discussion: A single immature specimen was recovered from the samples and is the first record of this species in the Arkadelphia marl. It has been reported previously from a single locality in the Austin chalk of Texas and from numerous localities in the Taylor, Navarro, and Midway of the Gulf Coast.

Neoflabellina reticulata (Reuss)

Pl. IV, figs. 13, 14

Flabellina reticulata Reuss, 1851, Haidinger's naturw. Abh., vol. 4, pt. 1, p. 30, pl. 1, fig. 22.
Flabellina favosa Beissel, 1891, K. Preuss. Geol. Landesanstalt, Abh., new ser., vol. 3, p. 49, pl. 19, figs. 25-28; pl. 26, fig. 28.
Frondicularia reticulata (Reuss). Bagg, 1898, U. S. Geol. Surv., Bull. 88, p. 50, pl. 3, fig. 6.
Frondicularia cf. *interpunctata* (Von der Marck). Cushman (*not* von der Marck), 1926, Amer. Assoc. Petrol. Geol., Bull., vol. 10, no. 6, p. 598, pl. 20, fig. 6.
Palmula reticulata (Reuss). Cushman, 1940, Foraminifera, Ed. 3, illus. key, p. 465, pl. 20, fig. 9.
Palmula reticulata (Reuss). Cushman and Todd, 1943, Cushman Lab. Foram. Res., Contr., vol. 19, pt. 3, p. 60, pl. 10, fig. 23. (synonymy).
Palmula reticulata (Reuss) Cushman. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 84, pl. 31, figs. 1-6. (synonymy).
Neoflabellina reticulata (Reuss). Bartenstein, 1948, Senckenbergiana, vol. 28, no. 4-6, p. 124.
Neoflabellina reticulata (Reuss). Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 97, pl. 12, figs. 13, 14.

Diagnosis: Test free, rhomboid in lateral view or with the base rounded, strongly compressed, periphery truncated, sides quite flat; microspheric juvenarium planispirally coiled; adult chambers chevron-shaped, narrow, extending back on both sides; chambers distinct; sutures distinct, somewhat raised; wall calcareous; surface covered by a raised meshwork with the long axis perpendicular to the sutures; aperture radiate, slightly produced.

Figured specimens: USNM 639506 (fig. 14), length 1.375 mm, breadth 0.90 mm; USNM 639507 (fig. 13), length 0.825 mm, collected 9 feet above the base. Compared with numerous plesiotypes in USNM: agree.

Discussion: This species is characteristic of the Navarro in the Gulf Coast and is confined to Navarro strata with one reported exception, the Taylor marl (upper part), Leon County, Texas.

Genus Frondicularia Defrance, 1824

Frondicularia Defrance, 1824, Dict. Sci. Nat., vol. 32, p. 178.

Type species: Renulina complanata Defrance, 1824. Subsequent designation, Cushman, 1913 [cited as *Frondicularia complanata* Defrance]. *Gender:* feminine.

Frondicularia inversa Reuss

Pl. IV, fig. 15

Frondicularia inversa Reuss, 1844, Geogn. Skizzen Böhmen, II: Die Kreidegebilde. . ., Prague: C. W. Medau, vol. 2, pt. 1, p. 211.
Frondicularia inversa Reuss. Cushman *(partim),* 1946, U. S. Geol. Surv., Prof. Paper 206, p. 86, pl. 33, figs. 16-18 (*not* figs. 11-15). (synonymy).
Frondicularia inversa Reuss. Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 98, pl. 12, figs. 31, 32.

Diagnosis: Test elongate, elliptical, quite strongly compressed, periphery rounded, with a short stout spine at the base; chambers distinct, proloculus narrow, elongate; adult chambers are progressively less embracing, giving a narrow tapered shape to the adult test; sutures distinct, flush, gently curved; wall calcareous; surface smooth or with a few fine vertical costae near the midline; aperture radiate, terminal.

Figured specimen: USNM 639508, length of broken specimen 1.325 mm (fig. 15), length of entire specimen 2.175 mm, maximum breadth 0.818 mm, collected 8 feet below the top. Compared with identified specimens in USNM: agrees with specimen identified by Reuss, except for the globular proloculus; agrees with specimens from the Selma chalk.

Discussion: This species is reported from the Austin, Taylor, and Navarro of Texas, Arkansas, and Tennessee.

Genus Pseudofrondicularia Thalmann, 1938

Pseudofrondicularia Wedekind, 1937, Einführung Grundl. Hist. Geol., vol. 2, p. 94. [Type species not explicitly designated.]
Pseudofrondicularia Thalmann, 1938, Paläont. Zentralblatt, Leipzig, vol. 11, no. 4, p. 210.

Type species: Frondicularia carinata Burbach, 1886. Original designation, Thalmann, 1938. *Gender:* feminine.

Pseudofrondicularia arkadelphiana (Cushman)

Pl. IV, fig. 16

Frondicularia arkadelphiana Cushman, 1936, Cushman Lab. Foram. Res., Contr., vol. 12, pt. 1, p. 12, pl. 3, figs. 2, 3.

Frondicularia arkadelphiana Cushman. CUSHMAN, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 91, pl. 37, figs. 21, 22.
Frondicularia arkadelphiana Cushman. CUSHMAN, 1949, U. S. Geol. Surv., Prof. Paper 221-A, p. 6.

Diagnosis: Test elongate, narrow, slightly tapering, periphery truncated, slightly concave, sides quite flat; proloculus spherical, somewhat thicker than the remainder of the test; adult chambers distinct, chevron-shaped, increasing gradually and regularly in size as added, not inflated; sutures distinct, strongly oblique, slightly curved, somewhat raised; wall calcareous, perforate; surface ornamented with fine, longitudinal, raised costae, somewhat finer and more numerous on the later chambers, the costae fusing into the raised sutural ridge at the base of each chamber; aperture small, radiate, terminal, elevated on a slight neck.

Figured specimen: USNM 639509, length of broken specimen 1.66 mm, breadth 0.575 mm, collected 10 feet below the top. Compared with the holotype and paratype in USNM: agrees favorably but more robust than the holotype and paratype.

Discussion: This species is restricted to strata of Navarro age and constitutes an excellent index fossil for the Arkadelphia and equivalents.

PSEUDOFRONDICULARIA LANCEOLA (Reuss)

Frondicularia lanceola REUSS, 1860, Akad. Wiss. Wien, Math.-naturw. Kl., Sitzb., vol. 40, p. 198, pl. 5, figs. 1a, b.
Frondicularia lanceola Reuss. CUSHMAN, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 85, pl. 33, figs. 1-4. (synonymy).
Frondicularia lanceola Reuss. CUSHMAN, 1949, U. S. Geol. Surv., Prof. Paper 221-A, p. 6, pl. 3, fig. 6.
Pseudofrondicularia lanceola (Reuss) var. *lanceola* (Reuss). FRIZZELL, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 100, pl. 13, figs. 16, 17.

Discussion: This species, reported by Cushman (1949) from the Arkadelphia, was not identified from the samples studied by the writer.

Family POLYMORPHINIDAE d'Orbigny, 1839

Subfamily POLYMORPHININAE d'Orbigny, 1839

Genus GUTTULINA d'Orbigny, 1839

Guttulina D'ORBIGNY, *in* DE LA SAGRA, 1839, Hist. Phys. Pol. Nat. Cuba, Foraminifères, p. 132.

Type species: Polymorphina (Guttulina) communis d'Orbigny, 1826. Subsequent designation, Galloway and Wissler, 1927. *Gender:* feminine.

GUTTULINA ADHAERENS (Olszewski)

Pl. IV, fig. 20

Polymorphina adhaerens OLSZEWSKI, 1875, Sprawozdonie Komisyi Fizyograficnéj, Akad. Umiejetnosci, Krakowie, vol. 9, p. 119, pl. 1, fig. 11.
Polymorphina communis d'Orbigny. CARSEY (*not* d'Orbigny), 1926, Texas Bur. Econ. Geol., Univ. Texas, Bull. 2612, p. 42, pl. 1, fig. 5.
Guttulina adhaerens (Olszewski). CUSHMAN and OZAWA, 1930, U. S. Natl. Mus., Proc., vol. 77, art. 6, p. 36, pl. 1, fig. 9; pl. 6, fig. 7.
Guttulina problema d'Orbigny. PLUMMER (*not* d'Orbigny), 1931, Texas Bur. Econ. Geol., Univ. Texas, Bull. 3101, p. 173, pl. 13, fig. 1.
Guttulina adhaerens (Olszewski) Cushman and Ozawa. CUSHMAN, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 96, pl. 40, figs. 8-10. (synonymy).
Guttulina adhaerens (Olszewski). FRIZZELL, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 103, pl. 14, figs. 16, 17.

Diagnosis: Test ovate to subovate, broadest below the middle, rounded at the base, acute at the apertural end; chambers clavate, arranged in a subquinqueloculine series, each succeeding chamber removed slightly farther from the base; sutures only slightly depressed, distinct; wall calcareous; surface smooth; aperture radiate, terminal.

Figured specimen: USNM 639510, length 0.465 mm, breadth 0.375 mm, collected 22 feet above the base. Compared with plesiotypes in USNM: agrees favorably.

Discussion: This species is reported from the upper Taylor and Navarro of the Gulf Coast.

Genus GLOBULINA d'Orbigny, 1839

Globulina D'ORBIGNY, *in* DE LA SAGRA, 1839, Hist. Phys. Pol. Nat. Cuba, Foraminifères, p. 134.

Type species: Polymorphina (Globuline) gibba d'Orbigny, 1826. Subsequent designation, Cushman, 1927 [cited as *Globulina gibba,* 1826]. *Gender:* feminine.

GLOBULINA LACRIMA LACRIMA Reuss

Pl. IV, fig. 21

Polymorphina (Globulina) lacrima REUSS, 1845, Versteiner. böhm. Kreidefm., pt. 1, p. 40, pl. 12, fig. 6; pl. 13, fig. 83.
Globulina lacrima Reuss. REUSS, 1851, Haidinger's naturw. Abh., vol. 4, pt. 1, p. 27, pl. 4, fig. 9.

Polymorphina gibba d'Orbigny. CUSHMAN (*not* d'Orbigny), 1926, Amer. Assoc. Petrol. Geol., Bull., vol. 10, no. 6, p. 604, pl. 20, figs. 8, 15.
Globulina lacrima Reuss. CUSHMAN, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 96, pl. 40, figs. 11, 12. (synonymy).
Globulina lacrima Reuss. CUSHMAN, 1949, U. S. Geol. Surv., Prof. Paper 221-A, p. 6, pl. 3, fig. 10.
Globulina lacrima (Reuss) var. *lacrima* (Reuss). FRIZZELL, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 104, pl. 14, figs. 21a-c.

Diagnosis: Test subglobular, base broadly rounded, apertural end produced, acuminate, rounded in transverse section; chambers few, enveloping earlier chambers almost to the base; sutures flush; wall calcareous; surface smooth; aperture radiate, produced into a slight neck.

Figured specimen: USNM 639511, length 0.40 mm, breadth 0.225 mm, collected 22 feet above the base. Compared with plesiotypes in USNM: compares favorably but is less globular.

Discussion: The typical subspecies is reported from numerous localities in the Austin, Taylor, and Navarro of the Gulf Coast.

GLOBULINA LACRIMA SUBSPHAERICA (Berthelin)

Pl. IV, fig. 22

Polymorphina subsphaerica BERTHELIN, 1880, Soc. Géol. France, Mém., sér. 3, vol. 1, pt. 5, p. 58, pl. 4, figs. 18a, b.
Globulina lacrima Reuss var. *subsphaerica* (Berthelin). CUSHMAN and OZAWA, 1930, U. S. Nat. Mus., Proc., vol. 77, art. 6, p. 78, pl. 19, figs. 5-7.
?Globulina inaequalis Reuss. SANDIDGE (*not* Reuss), 1932, Amer. Midland Nat., vol. 13, p. 359, pl. 31, figs. 25, 26.
Globulina lacrima Reuss var. *subsphaerica* (Berthelin) Cushman and Ozawa. CUSHMAN, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 96, pl. 40, fig. 13. (synonymy).
Globulina lacrima (Reuss) var. *subsphaerica* (Berthelin). FRIZZELL, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 104, pl. 14, figs. 22, 23.

Diagnosis: This form differs from the typical subspecies in the slightly compressed test which is more rounded at the base. The aperture is fistulose in some specimens.

Figured specimen: USNM 639512, length 0.45 mm, breadth 0.387 mm, collected 22 feet above the base. Compared with plesiotypes in USNM: compares favorably with the plesiotypes including one from the Arkadelphia which is fistulose.

Discussion: This subspecies is reported from the Taylor and Navarro of Texas, Arkansas, Mississippi, and Tennessee, and from the upper Cretaceous of Europe, Mexico, Nebraska, California, and New Jersey.

GLOBULINA LACRIMA HORRIDA Reuss

Pl. IV, fig. 23

Globulina horrida REUSS, 1846, Versteiner. böhm Kreidefm., pt. 2, p. 110, pl. 43, fig. 14.
Globulina lacrima Reuss var. *horrida* Reuss. CUSHMAN and OZAWA, 1930, U. S. Natl. Mus., Proc., vol. 77, art. 6, p. 79, pl. 19, fig. 3.
Globulina lacrima Reuss var. *horrida* Reuss. CUSHMAN, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 97, pl. 40, fig. 14. (synonymy).
Globulina lacrima (Reuss) var. *horrida* Reuss. FRIZZELL, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 104, pl. 14, fig. 20.

Diagnosis: This subspecies commonly has a fistulose aperture and differs from the typical form principally in the finely spinose surface.

Figured specimen: USNM 639513, length 0.30 mm, breadth 0.40 mm, collected 8 feet below the top. Compared with plesiotypes in USNM: compares favorably except some plesiotypes are not fistulose, including one from the Arkadelphia.

Discussion: This subspecies is reported from numerous localities in the Austin, Taylor, and Navarro of the Gulf Coast.

GLOBULINA PRISCA Reuss

Pl. IV, fig. 24

Globulina prisca REUSS, 1862, Akad. Wiss. Wien, Math.-naturw. Kl., Sitzb., vol. 46, pt. 1, p. 79, pl. 9, fig. 8.
Globulina prisca Reuss. CUSHMAN, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 97, pl. 40, figs. 15-17. (synonymy).
Globulina prisca Reuss. FRIZZELL, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 104, pl. 14, fig. 24.

Diagnosis: Test elongate, fusiform, somewhat compressed, apertural end acuminate, base rounded or acuminate; chambers elongate, tapering to the base, triloculine; sutures only slightly depressed; wall calcareous; surface smooth; aperture radiate.

Figured specimen: USNM 639514, length 0.525 mm, breadth 0.262 mm, collected 16 feet above the base. Compared with plesiotypes in USNM: compares favorably.

Discussion: This species is reported also from the Prairie Bluff chalk of Alabama, the Selma chalk of Mississippi, and the Annona chalk of Texas.

Genus PYRULINA d'Orbigny, 1839

Pyrulina D'ORBIGNY, *in* DE LA SAGRA, 1839, Hist. Phys. Pol. Nat. Cuba, Foraminifères, p. 107.

Type species: Polymorphina (Pyruline) gutta d'Orbigny, 1826. Monotypic. *Gender:* feminine.

PYRULINA CYLINDROIDES (Roemer)

Pl. IV, fig. 25

Polymorphina cylindroides ROEMER, 1838, Neues Jahrb., p. 385, pl. 3, fig. 26.
Polymorphina fusiformis Roemer. CUSHMAN (*not* Roemer), 1926, Amer. Assoc. Petrol. Geol., Bull., vol. 10, no. 6, p. 604, pl. 20, fig. 14.
Polymorphina gutta d'Orbigny. W. BERRY (*not* d'Orbigny), *in* BERRY and KELLEY, 1929, U. S. Natl. Mus., Proc., vol. 76, art. 19, p. 10, pl. 1, fig. 11.
Pyrulina cylindroides (Roemer). CUSHMAN and OZAWA, 1930, U. S. Natl. Mus., Proc., vol. 77, art. 6, p. 56, pl. 14, figs. 1-5.
Pyrulina cylindroides (Roemer) Cushman and Ozawa. CUSHMAN, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 97, pl. 40, figs. 18, 19. (synonymy).
Pyrulina cylindroides (Roemer). FRIZZELL, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 104, pl. 14, figs. 25-27.

Diagnosis: Test elongate, fusiform to subcylindrical, both ends acuminate, nearly circular in transverse section; chambers elongate, only partially embracing; juvenarium triloculine, adult chambers tending to appear biserial, progressively less embracing; sutures only slightly depressed; wall calcareous; surface smooth; aperture radiate.

Figured specimen: USNM 639515, length 0.538 mm, breadth 0.25 mm, collected 9 feet above the base. Compared with numerous plesiotypes in USNM: compares favorably.

Discussion: This species is widely distributed in the Taylor and Navarro of the Gulf Coast. It is rare in the Arkadelphia.

Genus PSEUDOPOLYMORPHINA Cushman and Ozawa, 1928

Pseudopolymorphina CUSHMAN and OZAWA, 1928, Cushman Lab. Foram. Res., Contr., vol. 4, pt. 1, p. 15.

Type species: Pseudopolymorphina hanzawai Cushman and Ozawa, 1928. Original designation. *Gender:* feminine.

PSEUDOPOLYMORPHINA CUYLERI Plummer

Pl. V, fig. 1

Pseudopolymorphina mendezensis (White). CUSHMAN and OZAWA (*partim;* not *Polymorphina mendezensis* White), 1930, U. S. Natl. Mus., Proc., vol. 77, art. 6, p. 109, pl. 28, figs. 7-9.
Pseudopolymorphina cuyleri PLUMMER, 1931, Texas Bur. Econ. Geol., Univ. Texas, Bull. 3101, p. 173, pl. 9, figs. 18-21.
Pseudopolymorphina cuyleri Plummer. CUSHMAN, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 98, pl. 41, figs. 2-10. (synonymy).
Pseudopolymorphina cuyleri Plummer. FRIZZELL, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 105, pl. 14, figs. 29-32.

Diagnosis: Test large, strongly compressed, tapering gradually from the rounded base to the maximum width at the base of the last-formed pair of chambers, periphery rounded, apertural end produced; chambers distinct, increasing gradually in breadth as added, height rather uniform throughout; sutures distinct, somewhat limbate, slightly depressed near the periphery in some adult specimens; wall calcareous, thickened, with additional thickening along the median axis of some specimens; surface generally smooth; aperture radiate, terminal.

Figured specimen: USNM 639516, length 1.85 mm, breadth 1.20 mm, collected 30 feet above the base. Compared with topotypes and plesiotypes in USNM: agrees.

Discussion: This species is reported only from the Arkadelphia marl of Arkansas, the Corsicana marl of Texas, and the Prairie Bluff chalk of Mississippi and Alabama. Thus, it is confined to Navarro strata.

Subfamily WEBBINELLINAE Rhumbler, 1904

Genus VITRIWEBBINA Chapman, 1892

Vitriwebbina CHAPMAN, 1892, Geol. Mag., new ser., decade 3, vol. 9, p. 52.

Type species: Vitriwebbina sollasi Chapman, 1927. *Gender:* feminine.

VITRIWEBBINA BIOSCULATA Frizzell

Pl. V, fig. 4

Bullopora laevis (Sollas). CUSHMAN and TODD (not *Webbina laevis* Sollas), 1943, Cushman Lab. Foram. Res., Contr., vol. 19, pt. 3, p. 63, pl. 11, fig. 8.
Bullopora laevis (Sollas) Wickenden. CUSHMAN (*partim;* not *Webbina laevis* Sollas), 1946, U. S. Geol. Surv., Prof. Paper 206, p. 98, pl. 42, figs. 1-4. (synonymy, *partim*).
Vitriwebbina biosculata FRIZZELL, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, pp. 107, 158, pl. 15, fig. 7.

Diagnosis: Test large, composed of a free globuline juvenarium, followed by a series of encrusting chambers, commonly branching; adult test attached to shell fragments, echinoid re-

mains, other foraminifers, or rarely inorganic detritus; juvenarium tiny, pear-shaped, with two to six chambers, lying parallel to and completely surrounded by the collar-like first encrusting chamber but with the upper half rising above it; encrusting chambers numerous (5 to 10 or more), extremely variable in shape and size, outline typically subcircular to trigonal, ranging to elongate or irregular, commonly "U-shaped" or "Y-shaped", slowly increasing in size as added, separated by the posterior neck-like projection of each chamber; wall calcareous, perforate; surface smooth; aperture multiple, one to four tiny produced openings on each chamber (typically two), situated at base of chamber, extra apertures open or connecting with chambers of branches of test.

Figured specimen: USNM 639517, length 1.16 mm, approximate diameter 0.35 mm, collected 16 feet above the base. Compared with plesiotypes of "*Bullopora laevis* (Sollas)" in USNM (one is now the holotype of this species): agrees.

Discussion: Vitriwebbina biosculata Frizzell is distinguished by its smooth surface from *V. tuberculata* (Sollas); and, by its multiple aperture from *V. laevis* (Sollas) and *V. chapmani* Plummer. It is reported from the Austin, Taylor, and Navarro strata of the Gulf Coast province (Frizzell, 1954).

Subfamily Ramulininae Brady, 1884

Genus Ramulina R. Jones, 1875

Ramulina Rupert Jones, *in* J. Wright, 1875, Belfast Nat. Field Club, Proc., new ser., vol. 1, appendix 3, p. 88.

Type species: Ramulina laevis R. Jones, 1875. Monotypic. *Gender:* feminine.

Ramulina arkadelphina Cushman

Pl. V, fig. 2

Ramulina arkadelphiana Cushman, 1938, Cushman Lab. Foram. Res., Contr., vol. 14, pt. 2, p. 43, pl. 7, figs. 12-14.
Ramulina arkadelphiana Cushman. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 99, pl. 43, figs. 3-8.
Ramulina arkadelphiana Cushman. Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 105, pl. 14, figs. 40-43.

Diagnosis: Test free, consisting of irregularly elongate or fusiform chambers with somewhat tapering tubular projections extending in various directions; wall calcareous, thin; surface finely hispid; apertures simple, the open ends of the tubes.

Figured specimen: USNM 639518, length 0.65 mm, maximum diameter 0.175 mm, collected 8 feet below the top. Compared with the holotype and paratypes in USNM: agrees.

Discussion: This species is distinguished by its irregular form and the finely hispid surface. It is restricted to Navarro strata.

Ramulina globotubulosa Cushman

Pl. V, fig. 3

Ramulina sp. (?). Cushman, 1931, Tennessee Div. Geol., Bull. 41, p. 42, pl. 7, fig. 1.
Ramulina globo-tubulosa Cushman, 1938, Cushman Lab. Foram. Res., Contr., vol. 14, pt. 2, p. 44, pl. 7, fig. 16.
Ramulina globo-tubulosa Cushman. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 100, pl. 43, fig. 10.
Ramulina globo-tubulosa Cushman. Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 106, pl. 14, fig. 49.

Diagnosis: Test small, subspherical with fine tubular projections radiating from the inflated central chamber; wall calcareous; surface finely hispid; apertures simple, the open ends of the tubular projections.

Figured specimen: USNM 639519, length 0.55 mm, diameter of central chamber 0.225 mm, collected 8 feet below the top. Compared with the holotype in USNM: agrees perfectly.

Discussion: This is the first record of this species in the Arkadelphia. It is reported from the Austin, Taylor, and Navarro strata of the Gulf Coast.

Superfamily Buliminacea Jones, 1875

Family Turrilinidae Cushman, 1927

Subfamily Turrilininae Cushman, 1927

Genus Buliminella Cushman, 1911

Buliminella Cushman, 1911, U. S. Natl. Mus., Bull. 71, pt. 2, p. 88.

Type species: Bulimina elegantissima d'Orbigny, 1839. Original designation [cited as *Buliminella elegantissima* (d'Orbigny)]. *Gender:* feminine.

Buliminella cushmani Sandidge

Pl. V, fig. 21

Buliminella cushmani Sandidge, 1932, Jour. Paleontology, vol. 6, no. 3, p. 280, pl. 42, figs. 18, 19.
Buliminella cushmani Sandidge. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 119, pl. 50, fig. 15. (synonymy).
Buliminella cushmani Sandidge. Cushman, 1949,

U. S. Geol., Surv., Prof. Paper 221-A, p. 8, pl. 4, fig. 2.
Buliminella cushmani Sandidge. FRIZZELL, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 114, pl. 16, figs. 40a, b.

Diagnosis: Test small, compact, fusiform, spirally coiled, involute, circular in transverse section, base pointed, apertural end gradually tapering and rounded; chambers numerous, four in the last-formed volution, slightly inflated; sutures distinct, depressed; wall calcareous, thin, finely perforate; surface smooth; aperture loop-shaped, comma-like, extending from near the apex to the basal margin of the last-formed chamber. Length of holotype 0.4 mm.

Figured specimen: USNM 639520, length 0.225 mm, maximum diameter 0.15 mm, collected 8 feet below the top. Compared with plesiotypes in USNM: agrees.

Discussion: This form is smaller and more compact than *Buliminella carseyae* Plummer and the sutures curve more gracefully than in the latter. *B. cushmani* Sandidge is reported from the Austin, Taylor, and Navarro strata.

Family BOLIVINITIDAE Cushman, 1927

Subfamily BOLIVINITINAE Cushman, 1927

Genus BOLIVINITA Cushman, 1927

Bolivinita CUSHMAN, 1927, Cushman Lab. Foram. Res., Contr., vol. 2, pt. 4, p. 90.

Type species: Textularia quadrilatera Schwager, 1866. Original designation [cited as *Bolivinita quadrilatera* (Schwager)]. *Gender:* feminine.

BOLIVINITA COSTIFERA Cushman

Bolivinita costifera CUSHMAN, 1937, Cushman Lab. Foram. Res., Contr., vol. 13, pt. 4, p. 105, pl. 15, figs. 15a, b.
Bolivinita costifera Cushman. CUSHMAN, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 115, pl. 49, fig. 3.
Bolivinita costifera Cushman. CUSHMAN, 1949, U. S. Geol. Surv., Prof. Paper 221-A, p. 8.

Discussion: This species, reported (questionably) by Cushman (1949) from the Arkadelphia, was not identified from the samples studied by the writer. The holotype and numerous paratypes in the USNM were examined.

Subfamily BOLIVINITINAE Glaessner, 1937

Genus BOLIVINA d'Orbigny, 1839

Bolivina D'ORBIGNY, 1839, Voyage Amer. Merid., vol. 5, pt. 5, p. 61.

Type species: Bolivina plicata d'Orbigny, 1839. Subsequent designation, Cushman, 1911. *Gender:* feminine.

BOLIVINA INCRASSATA Reuss

Bolivina incrassata REUSS, 1851, Haidinger's Naturw. Abh., vol. 4, p. 29, pl. 4, fig. 13.
Bolivina incrassata Reuss var. *lata* EGGER, 1899, K. Bayer. Akad. Wiss., Math.-naturh., Abt., Abh., Kl. 2, vol. 21, pt. 1, p. 46, pl. 16, figs. 8, 9.
Bolivina primatumida WHITE, 1929, Jour. Paleontology, vol. 3, no. 1, p. 44, pl. 4, figs. 20a, b.
Bolivina incrassata Reuss. CUSHMAN, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 127, pl. 53, figs. 8-11. (synonymy).
Bolivina incrassata Reuss. CUSHMAN, 1949, U. S. Geol. Surv., Prof. Paper 221-A, p. 8, pl. 4, fig. 6.
"*Bolivina incrassata* Reuss". FRIZZELL, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 117, pl. 17, fig. 25.

Discussion: This species, reported by Cushman (1949) from the Arkadelphia, was not identified from the samples studied by the writer.

BOLIVINA DECURRENS (Ehrenberg)

Grammostomum? decurrens EHRENBERG, 1854, Mikrogeologie, p. 22, pl. 30, fig. 17.
Bolivina decurrens (Ehrenberg). MARSSON, 1878, Naturw. Ver., Neu-Vorpommern u. Rügen, Greifswald, Mitt., Berlin, Jahrg. 10, p. 156, pl. 3, fig. 24.
Bolivina decurrens (Ehrenberg) Marsson. CUSHMAN, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 127, pl. 53, figs. 12, 13. (synonymy).
Bolivina decurrens (Ehrenberg) Marsson. CUSHMAN, 1949, U. S. Geol. Surv., Prof. Paper 221-A, p. 9, pl. 4, fig. 7.
Bolivina decurrens (Ehrenberg). FRIZZELL, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 117, pl. 17, fig. 24.

Discussion: This species, reported by Cushman (1949) from the Arkadelphia, was not identified from the samples studied by the writer.

Genus LOXOSTOMUM Ehrenberg, 1854

Loxostomum EHRENBERG, 1854, Mikrogeologie, p. 22.

Type species: Loxostomum subrostratum Ehrenberg, 1854. Subsequent designation, Cushman, 1928. *Gender:* neuter.

Loxostomum cushmani Wickenden

Pl. V, fig. 26

Loxostomum clavatum (Cushman). Cushman (*partim;* not *Bolivina clavata* Cushman), 1932, Jour. Paleontology, vol. 6, no. 4, p. 340, pl. 51, figs. 8a, b.
Loxostomum cushmani Wickenden, 1932, Royal Soc. Canada, Trans., third ser., vol. 26, sec. 4, p. 91, pl. 1, figs. 6a, b.
Loxostoma cushmani Wickenden. Cushman and Deaderick, 1942, Cushman Lab. Foram. Res., Contr., vol. 18, pt. 3, p. 63, pl. 15, figs. 11-13.
Loxostoma cushmani Wickenden. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 129, pl. 53, figs. 24-31. (synonymy).
Loxostomum cushmani Wickenden. Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 118, pl. 17, figs. 32-34.

Diagnosis: Test elongate, narrow, slightly tapering, only slightly compressed, periphery rounded, juvenarium distinctly biserial, tending to become uniserial in the adult; chambers distinct, particularly in the later portion, adult chambers inflated, slightly overlapping; sutures distinct, early ones horizontal and not depressed, gradually becoming deeply depressed and oblique in the adult with distinct re-entrants or lobed sutural processes; wall calcareous; surface smooth or with faint longitudinal costae in juvenarium, adult smooth except for the crenulations at the base of the chambers; aperture of adult rounded, terminal.

Figured specimen: USNM 639521, length 0.90 mm, breadth 0.175 mm, collected 8 feet below the top. Compared with two paratypes in USNM: agrees, but immature. The paratypes have globular final chambers which the Arkadelphia specimen lacks.

Discussion: This form is extremely rare in the Arkadelphia. It occurs widely in the Austin, Taylor, and Navarro of the Gulf Coast province.

Loxostomum gemma (Cushman)

Pl. V, figs. 27, 28

Bolivina gemma Cushman, 1927, Cushman Lab. Foram. Res., Contr., vol. 2, pt. 4, p. 87, pl. 12, figs. 3a, b. [The species-group name is a noun in apposition.]
Loxostoma gemmum (Cushman). Cushman, 1937, Cushman Lab. Foram. Res., Spec. Pub. 9, p. 172, pl. 20, figs. 14-16.
Loxostoma gemmum (Cushman) Cushman. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 129, pl. 54, figs. 1-3.
Loxostomum gemma (Cushman). Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 118, pl. 17, figs. 35a, b.

Diagnosis: Test elongate, somewhat tapering, compressed, periphery rounded, biserial throughout, slightly twisted in the earlier portion; chambers distinct, numerous, increasing regularly in size and breadth as added, slightly inflated in the adult stage; sutures distinct, somewhat limbate, slightly depressed toward the periphery, axial margin raised, forming a "zigzag" row of beads of clear shell material, particularly in the earlier portion of the test; wall calcareous, thick, finely perforate; surface smooth except for the beaded ornamentation and fine striations near the base of some specimens; aperture elongate, elliptical, slightly curved, becoming terminal in the adult.

Figured specimens: USNM 639522 (fig. 27), length 0.76 mm, breadth 0.24 mm; USNM 639523 (fig. 28), collected 8 feet below the top. Compared with the holotype and paratypes in USNM: agree exactly.

Discussion: This species is restricted to Navarro strata. It is distinguished by the distinct beaded ornamentation.

Loxostomum plaitum (Carsey)

Pl. V, fig. 29

Bolivina plaita Carsey, 1926, Texas Bur. Econ. Geol., Univ. Texas, Bull. 2612, p. 26, pl. 4, fig. 2.
Proroporus plaita (Carsey). Cushman, 1927, Cushman Lab. Foram. Res., Contr., vol. 2, pt. 4, p. 89, pl. 12, figs. 7a, b.
Loxostomum plaitum (Carsey). Cushman, 1928, Cushman Lab. Foram. Res., Spec. Pub. 1, p. 254, pl. 37, fig. 9.
Loxostoma plaitum (Carsey) Cushman. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 130, pl. 54, figs. 10-14. (synonymy).
Loxostomum plaitum (Carsey) var. *plaitum* (Carsey). Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 118, pl. 17, fig. 38.

Diagnosis: Test quite elongate, slender, slightly tapering, slightly twisted, compressed, periphery rounded, maximum breadth toward the apertural end; chambers numerous, distinct, increasing rapidly in height as added; juvenarium biserial, chambers slightly inflated; adult chambers strongly inflated, tending to become uniserial; sutures distinct, slightly depressed, commonly somewhat limbate, earlier sutures strongly oblique and slightly curved, later sutures strongly curved; wall calcareous, finely perforate; surface smooth; aperture tending to become terminal in the adult, narrowly ovate.

Figured specimen: USNM 639524, length 0.60 mm, breadth 0.14 mm, collected 8 feet below the top. Compared with identified specimens in USNM: compares favorably.

Discussion: This species is abundant and widely distributed in strata of Navarro age, but is less common in the Taylor and Austin.

Family EOUVIGERINIDAE Cushman, 1927

Genus PSEUDOUVIGERINA Cushman, 1927

Pseudouvigerina CUSHMAN, 1927, Cushman Lab. Foram. Res., Contr., vol. 2, pt. 4, p. 81.

Type species: Uvigerina cristata Marsson, 1878. Original designation. *Gender:* feminine.

PSEUDOUVIGERINA SELIGI (Cushman)

Pl. V, fig. 19

Uvigerina seligi CUSHMAN, 1925, Cushman Lab. Foram. Res., Contr., vol. 1, pt. 1, p. 1, pl. 4, figs. 1a-c.
Uvigerina tenuistriata Reuss. CARSEY (*not* Reuss), 1926, Texas Bur. Econ. Geol., Univ. Texas, Bull. 2612, p. 42, pl. 1, fig. 1.
Eouvigerina americana Cushman. ALBRITTON and PHLEGER (*not* Cushman), 1937, Jour. Paleontology, vol. 11, no. 4, p. 351.
Pseudouvigerina seligi (Cushman). CUSHMAN and TODD, 1943, Cushman Lab. Foram. Res., Contr., vol. 19, pt. 3, p. 65, pl. 11, figs. 19a, b.
Pseudouvigerina seligi (Cushman) Cushman and Todd. CUSHMAN, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 117, pl. 49, figs. 21-24. (synonymy).
Pseudouvigerina seligi (Cushman). FRIZZELL, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 113, pl. 16, figs. 34, 35a, b.

Diagnosis: Test minute, elongate; chambers few, the final three comprising the major portion of the test, angled, the basal portion of each chamber sharply undercut forming an overhanging shoulder; sutures distinct, depressed; wall calcareous; surface of chambers roughened, with a few prominent longitudinal costae independent of adjacent chambers; aperture circular, elevated on a short, broad, cylindrical neck with a phialine lip.

Figured specimen: USNM 639525, length 0.30 mm, breadth 0.138 mm, collected 16 feet above the base. Compared with plesiotypes in USNM: agrees. The cotypes were obscured by a moldy coating and were inaccessible for comparison.

Discussion: This species is restricted to strata of Navarro age, but is widely distributed in the Gulf Coast localities. The types are from the Arkadelphia marl in the subsurface of Bossier Parish, Louisiana.

Genus SIPHOGENERINOIDES Cushman, 1927

Siphogenerinoides CUSHMAN, 1927, Cushman Lab. Foram. Res., Contr., vol. 3, pt. 1, p. 63.
Siphogenerinoides Cushman, emend. STONE, 1946, Jour. Paleontology, vol. 20, no. 5, pp. 465-469.

Type species: Siphogenerina plummeri Cushman, 1926. Original designation [cited as *Siphogenerinoides plummeri* Cushman]. *Gender:* masculine.

SIPHOGENERINOIDES PLUMMERI (Cushman)

Pl. V, fig. 20

Siphogenerina plummeri CUSHMAN, 1926, U. S. Natl. Mus., Proc., vol. 67, art. 25, p. 18.
Siphogenerinoides plummeri Cushman. CUSHMAN, 1927, Cushman Lab. Foram. Res., Contr., vol. 3, pt. 1, p. 63, pl. 13, fig. 16.
Siphogenerinoides plummeri (Cushman) Cushman. CUSHMAN, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 117, pl. 50, figs. 1a, b. (synonymy).
Siphogenerinoides plummeri (Cushman). STONE, 1946, Jour. Paleontology, vol. 20, no. 5, p. 469, pl. 71, figs. 2a, b, 3, 26.
Siphogenerinoides plummeri (Cushman). FRIZZELL, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 113, pl. 16, figs. 36a, b.

Diagnosis: Test elongate, slightly tapering, broadest at the last-formed chamber, 4 to 5 times as long as broad; apertural end broadly rounded; base of megalospheric form bluntly rounded, slightly spinose in some specimens; base of microspheric form attenuate, biserial stage flattened and twisted in most specimens; microspheric juvenarium triserial, then biserial, later symmetrically uniserial; megalospheric proloculus followed by several biserial chambers, then symmetrically uniserial; wall calcareous, hyaline, conspicuously perforate; surface ornamented by 8 to 13 sharp longitudinal costae continuous over the sutures or broken into small downward-projecting spines at the base of the chambers, also ornamented by less distinct minor costae; sutures retroflexed along the major costae, depressed slightly in the earlier test and more clearly depressed in the adult; internal siphon reaching from the initial chambers to the last-formed, twisting about 90° per chamber as it passes through the test, the uppermost end forming a small separate opening outside of and tangent to the aperture on the concave side, the unattached upper edge of the siphon formed by the concave apertural lip which may be broken or incompletely fused, the other edge of the siphon continuous with the septal face of the last-formed chamber which is slightly upwarped near the edge of the siphon; aperture central, terminal, sharply arcuate, on a short neck with a flaring phialine lip, commonly broken along the concave side.

Figured specimen: USNM 639526, length 0.80 mm, diameter 0.20 mm, collected 8 feet below the top. Compared with the holotype in USNM: agrees.

Discussion: This species is restricted to strata of Navarro age. It is distinctive and serves as an excellent index fossil.

SIPHOGENERINOIDES BREVISPINOSA Cushman

Siphogenerinoides brevispinosa CUSHMAN, 1939,

Cushman Lab. Foram. Res., Contr., vol. 15, pt. 4, p. 92, pl. 16, figs. 7a, b.
Siphogenerinoides brevispinosa Cushman. CUSHMAN, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 119, pl. 50, fig. 12.
Siphogenerinoides brevispinosa Cushman. STONE, 1946, Jour. Paleontology, vol. 20, no. 5, p. 472, pl. 71, figs. 5-7, 27.
Siphogenerinoides brevispinosa Cushman. CUSHMAN, 1949, U. S. Geol. Surv., Prof. Paper 221-A, p. 8.

Discussion: This species reported (questionably) by Cushman (1946, 1949) from the Arkadelphia, was not identified from the samples studied by the writer. The holotype and paratypes in the USNM were examined.

Family BULIMINIDAE Jones, 1875

Subfamily BULIMININAE Jones, 1875

Genus BULIMINA d'Orbigny, 1826

Bulimina D'ORBIGNY, 1826, Ann. Sci. Nat., sér. 1, vol. 7, p. 269.

Type species: Bulimina marginata d'Orbigny, 1826. Subsequent designation, Cushman, 1911. *Gender:* feminine.

BULIMINA ASPERA Cushman and Parker

Pl. V, fig. 22

Bulimina pupoides d'Orbigny. CARSEY (*not* d'Orbigny), 1926, Texas Bur. Econ. Geol., Univ. Texas, Bull. 2612, p. 29, pl. 4, fig. 3.
Bulimina obtusa d'Orbigny. CUSHMAN and CHURCH (*not* d'Orbigny), 1929, California Acad. Sci., Proc., ser. 4, vol. 18, p. 513, pl. 39, figs. 17-19.
Bulimina subornata Brady. SANDIDGE (*not* Brady), 1932, Jour. Paleontology, vol. 6, no. 3, p. 280, pl. 43, fig. 2.
[?] *Bulimina elongata* d'Orbigny. SANDIDGE (*not* d'Orbigny), 1932, Jour. Paleontology, vol. 6, no. 3, p. 281, pl. 43, fig. 3.
Bulimina quadrata Plummer. CUSHMAN and PARKER (*partim; not* Plummer), 1935, Cushman Lab. Foram. Res., Contr., vol. 11, pt. 4, p. 100, pl. 15, figs. 12, 15, 16 (*not* 13, 14).
Bulimina kickapooensis COLE *(partim),* 1938, Florida Dept. Conserv., Geol. Bull. 16, p. 45.
Bulimina aspera CUSHMAN and PARKER, 1940, Cushman Lab. Foram. Res., Contr., vol. 16, pt. 2, p. 44, pl. 8, figs. 18, 19.
Bulimina aspera Cushman and Parker. CUSHMAN, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 121, pl. 51, figs. 7, 10, 13, 15, 16. (synonymy).
Bulimina aspera Cushman and Parker. FRIZZELL, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 114, pl. 16, figs. 43-46.

Diagnosis: Test medium size, slightly tapering consisting of 4 to 5 volutions, base bluntly pointed, commonly bearing one or two short basal spines; chambers joined at an angle of 90 degrees or less, slightly inflated; sutures distinct, slightly depressed; wall calcareous; surface of initial part of test roughened, perforated, with the perforations commonly arranged in regular lines; aperture elongate, at apex of test, with a small plate-like tooth.

Figured specimen: USNM 639527, length 0.40 mm, diameter 0.20 mm, collected 8 feet below the top. Compared with the holotype and paratypes in USNM: agrees perfectly.

Discussion: This species is reported from numerous localities in the Taylor and Navarro of the Gulf Coast.

BULIMINA PROLIXA Cushman and Parker

Bulimina puschi Reuss. CUSHMAN (*not* Reuss), 1931, Tennessee Div. Geol., Bull. 41, p. 47, pl. 7, figs. 19a, b.
Bulimina prolixa CUSHMAN and PARKER, 1935, Cushman Lab. Foram. Res., Contr., vol. 11, pt. 4, p. 98, pl. 15, figs. 5a, b.
Bulimina prolixa Cushman and Parker. CUSHMAN, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 122, pl. 51, figs. 19-22. (synonymy).
Bulimina prolixa Cushman and Parker. CUSHMAN, 1949, U. S. Geol. Surv., Prof. Paper 221-A, p. 8, pl. 4, fig. 4.
Bulimina prolixa Cushman and Parker. FRIZZELL, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 115, pl. 17, figs. 4, 5.

Discussion: This species, reported by Cushman (1949) from the Arkadelphia, was not identified from the samples studied by the writer. The holotype and paratypes in the USNM were examined.

BULIMINA ARKADELPHIANA Cushman and Parker

Pl. V, figs. 23, 24

Bulimina arkadelphiana CUSHMAN and PARKER, 1935, Cushman Lab. Foram. Res., Contr., vol. 11, pt. 4, p. 96, pl. 15, figs. 1, 2.
Bulimina arkadelphiana Cushman and Parker. CUSHMAN, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 124, pl. 52, figs. 3, 4.

Diagnosis: Test small to medium size, tapering, the megalospheric form consisting of about 5 volutions and considerably smaller than the microspheric form with about 8 volutions; chambers numerous, adult ones inflated; sutures distinct, deeply depressed; wall calcareous, finely perforate; surface of lower portion of chambers covered with sharp spines, especially prominent at the lower margins; aperture elongate with a small lip.

Figured specimens: USNM 639528 (fig. 23), length 0.50 mm, maximum diameter 0.25 mm; USNM 639529 (fig. 24), collected 16 feet above the base. Compared with the

holotype and paratypes in USNM: agree perfectly.

Discussion: This form is restricted to the Arkadelphia marl. It is easily recognized by its striking ornamentation.

Superfamily Asterigerinacea d'Orbigny, 1839

Family Discorbidae Cushman, 1927

Subfamily Discorbinae Cushman, 1927

Genus Gyroidina d'Orbigny, 1826

Gyroïdina d'Orbigny, 1826, Ann, Sci. Nat., sér. 1, vol. 7, p. 278.

Type species: Gyroidina orbicularis d'Orbigny, 1826. Subsequent designation, Cushman, 1927 [cited as *Gyroidina orbiculus* d'Orbigny]. *Gender:* feminine.

Gyroidina depressa (Alth)

Pl. VI, figs. 1, 2, 3, 4

Rotalina depressa Alth, 1850, Haidinger's naturw. Abh., vol. 3, p. 266, pl. 13, fig. 21.
Rotalia cretacea Carsey, 1926, Texas Bur. Econ. Geol., Univ. Texas, Bull. 2612, p. 48, pl. 5, figs. 1a, b.
Rotalia beccarii Linnaeus, var. *ripleyensis* W. Berry, *in* Berry and Kelley, 1929, U. S. Natl. Mus., Proc., vol. 76, art. 19, p. 15, pl. 3, figs. 10-12.
Gyroidina depressa (Alth). Cushman and Church, 1929, California Acad. Sci., Proc., ser. 4, vol. 18, p. 515, pl. 41, figs. 4-6.
Valvulineria cretacea (Carsey). Cushman and Todd, 1943, Cushman Lab. Foram. Res., Contr., vol.19, pt. 3, p. 67, pl. 12, figs. 1a-c.
Valvulineria cretacea (Carsey) Cushman and Todd. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 138, pl. 57, figs. 8a-c.
Gyroidina depressa (Alth) Cushman and Church. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 139, pl. 58, figs. 1-4. (synonymy).
Valvulineria cretacea (Carsey) Cushman and Todd. Cushman, 1949, U. S. Geol. Surv., Prof. Paper 221-A, p. 9.
Gyroidina depressa (Alth) Cushman and Church. Cushman, 1949, U. S. Geol. Surv., Prof. Paper 221-A, p. 9, pl. 4, figs. 12, 13.
Gyroidina depressa (Alth). Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 123, pl. 18, figs. 36a-c.

Diagnosis: Test trochoid, biconvex, compressed, the dorsal side somewhat flattened, periphery rounded; chambers distinct, numerous, 10 to 12 in the last-formed volution; sutures distinct, gently curved, slightly limbate and nearly flush on the dorsal surface, radial and slightly depressed on the ventral surface; wall calcareous; surface smooth; aperture low, eccentric on the ventral side near the umbilicus.

Figured specimens: USNM 639530 (fig. 1, 2), maximum diameter 0.30 mm; USNM 639531 (fig. 3); USNM 639532 (fig. 4), collected 8 feet below the top. Compared with identified specimens in USNM: compares favorably.

Discussion: This species is common in the Austin, Taylor, and Navarro strata of Texas, Arkansas, Mississippi, Alabama, and Tennessee.

Gyroidina arkadelphiana Cushman

pl. VI, figs. 5, 6

Gyroidina arkadelphiana Cushman, 1938, Cushman Lab. Foram. Res., Contr., vol. 14, pt. 2, p. 49, pl. 8, figs. 7a-c.
Gyroidina arkadelphiana Cushman. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 141, pl. 58, figs. 10a-c.

Diagnosis: Test planoconvex, dorsal surface flattened or slightly concave, ventral surface strongly convex with a large, deep umbilicus, periphery rounded, somewhat angled and raised at the edge of the dorsal surface; chambers numerous, about 10 in the adult volution, increasing rapidly in size and width on the ventral side; sutures distinct, radial, slightly depressed; wall calcareous; surface smooth except for raised ridges on the dorsal surface representing the angled margins of the preceding chambers; aperture elongate, at the inner margin of the last-formed chamber on the ventral side.

Figured specimen: USNM 639533, height 0.30 mm, maximum diameter 0.45 mm, collected 16 feet above the base. Compared with the holotype and paratype in USNM: agrees perfectly.

Discussion: This species is known only from the Arkadelphia marl, Hempstead County, Arkansas.

Genus Stensioina Brotzen, 1936

Stensiöina Brotzen, 1936, Sveriges Geol. Undersökning, Afh., ser. C, no. 396, vol. 30, pt. 3, p. 315.

Type species: Rotalia exsculpta Reuss, 1860. Original designation [cited as *Stensiöina exsculpta* (Reuss)]. *Gender:* feminine.

Stensioina americana Cushman and Dorsey

Pl. VI, figs. 7, 8

Cibicides excolata (Cushman). Cushman (not *Truncatulina excolata* Cushman, 1926), 1931, Jour. Paleontology, vol. 5, no. 4, p. 315, pl. 36, figs. 8a-c.

Stensiöina americana (Cushman). Cole (*not* Cushman), 1938, Florida Dept. Conserv., Geol. Bull. 16, p. 35, pl. 3, figs. 2, 3.
Stensiöina americana Cushman and Dorsey, 1940, Cushman Lab. Foram. Res., Contr., vol. 16, pt. 1, p. 5, pl. 1, figs. 7a-c.
Stensiöina americana Cushman and Dorsey. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 141, pl. 65, figs. 14a-c. (synonymy).
Stensiöina americana Cushman and Dorsey. Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 124, pl. 19, figs. 5a-c.

Diagnosis: Test small, trochoid, dorsal side flattened and slightly concave in central portion, peripheral margin acutely keeled, ventral side broadly convex, forming an angle of less than 90° with the dorsal side, umbonate, umbilical area flat to depressed; chambers distinct, uniform, increasing regularly in size as added, about 8 in the last-formed volution; sutures on the dorsal side distinct, raised, marked by irregular, broken, gently curved costae, spiral suture indistinct, irregular, and broken, sutures on the ventral side slightly depressed, gently curved, marked by narrow bands of clear shell material; wall calcareous, coarsely perforate; ventral surface smooth, dorsal surface roughened; aperture eccentric, an elongate, low, arched slit midway between the umbo and the keeled periphery.

Figured specimen: USNM 639534, diameter 0.275 mm, collected 8 feet below the top. Compared with the holotype and paratypes in USNM: agrees perfectly.

Discussion: This species is distinguished from *S. excolata* (Cushman) by its smaller size and concave dorsal surface. It is reported from the Taylor and Navarro of Texas, Arkansas, and Alabama. This is the first record from the Arkadelphia marl.

Family Siphoninidae Cushman, 1927

Genus Siphonina Reuss, 1850

Siphonina Reuss, 1850, Akad. Wiss. Wien, Math.-naturw. Kl., Denkschr., vol. 1, p. 372.

Type species: Siphonina fimbriata Reuss, 1850. Monotypic. *Gender:* feminine.

Siphonina prima Plummer

Pl. VI, figs. 9, 10

Siphonina prima Plummer, 1927, Texas Bur. Econ. Geol., Univ. Texas, Bull. 2644, p. 148, pl. 12, figs. 4a-c.
Siphonina prima Plummer. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 143, pl. 59, figs. 3-5. (synonymy).
Siphonina prima Plummer. Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 125, pl. 19, figs. 8a-c.

Diagnosis: Test minute, subcircular, biconvex, strongly convex, periphery sharply acute and delicately serrate, slightly lobate; typically 5 chambers in the last-formed volution, slightly inflated on the ventral side; sutures curved, not depressed, marked by the serrate edges of the chambers on the dorsal side, nearly radial on the ventral side, slightly curved, somewhat depressed; wall calcareous, distinctly and coarsely perforate; surface smooth; aperture small, narrowly elliptical, parallel to and just ventral to the periphery, without a distinct neck.

Figured specimen: USNM 639535, maximum diameter 0.21 mm, collected 8 feet below the top. Compared with identified specimens and plesiotypes in USNM: agrees.

Discussion: This species is reported from the Midway (Paleocene) of Texas and from the Navarro of Texas, Arkansas, Mississippi, Alabama, and Tennessee.

Superfamily Globigerinacea Carpenter, Parker and Jones, 1862

Family Heterohelicidae Cushman, 1927

Subfamily Guembelitriinae Montanaro Gallitelli, 1957

Genus Guembelitria Cushman, 1933

Gümbelitria Cushman, 1933, Cushman Lab. Foram. Res., Contr., vol. 9, pt. 2, p. 37.

Type species: Gümbelitria cretacea Cushman, 1933. Original designation. *Gender:* feminine.

Guembelitria cretacea Cushman

Pl. V, fig. 13

Gümbelitria cretacea Cushman, 1933, Cushman Lab. Foram. Res., Contr., vol. 9, pt. 2, p. 37, pl. 4, figs. 12a, b.
Gümbelitria cretacea Cushman. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 103, pl. 44, figs. 14a, b. (synonymy).
Gümbelitria cretacea Cushman. Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 110, pl. 15, figs. 45a, b.

Diagnosis: Test quite small, triserial; chambers globular, nearly spherical; sutures strongly depressed; wall calcareous, finely perforate; surface smooth; aperture large, semicircular, at the inner margin of the last-formed chamber.

Figured specimen: USNM 639536, length 0.19 mm, breadth 0.125 mm, collected 8 feet below the top. Compared with several plesiotypes in USNM: compares favorably.

Discussion: This is the first record for the form from the Arkadelphia. It is restricted to the Navarro strata of Texas, Arkansas, Mississippi, and Alabama.

Subfamily HETEROHELICINAE Cushman, 1927

Genus HETEROHELIX Ehrenberg, 1843

Heterohelix EHRENBERG, 1843, K. Akad. Wiss. Berlin, Physik. Abh., (Jahrg. 1841), p. 429.
Heterohelix Ehrenberg, emend. LOEBLICH, 1951, Cushman Foundation Foram. Res., Contr., vol. 2, pt. 3, p. 107.

Type species: Spiroplecta americana Ehrenberg, 1844 = *Heterohelix* sp. Ehrenberg, 1843. First and only species assigned to the genus by Ehrenberg (Loeblich, 1951). *Gender:* feminine.

HETEROHELIX PLUMMERAE (Loetterle)

Pl. V, fig. 9

Gümbelina plummerae LOETTERLE, 1937, Nebraska Geol. Surv., ser. 2, Bull. 12, p. 33, pl. 5, figs. 1, 2. [not *Ventilabrella plummerae* Sandidge, 1932 = *Guembelina carseyae* (Plummer).]
Gümbelina plummerae Loetterle. CUSHMAN *(partim),* 1946, U. S. Geol. Surv., Prof. Paper 206, p. 104, pl. 45, figs. 1-3. (synonymy, *partim*).
Gümbelina plummerae Loetterle. FRIZZELL, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 109, pl. 15, figs. 36a, b.

Diagnosis: Test comparatively large, stout, juvenarium rapidly tapering, adult test gradually tapering or even contracted, thickness commonly greater than breadth, early periphery slightly keeled, later deeply indented; adult chambers strongly inflated, some specimens with one or more irregularly placed terminal chambers resembling *Planoglobulina* Cushman; sutures depressed, somewhat curved in the adult portion; wall calcareous; surface distinctly costate, less markedly in the later chambers; aperture a low, broad arch with a slight lip.

Figured specimen: USNM 639537, length 0.45 mm, breadth 0.31 mm, collected 8 feet below the top. Compared with plesiotypes in USNM: the plesiotypes are more strongly inflated and tapered.

Discussion: This species is reported from numerous localities in the Austin, Taylor, and Navarro of the Gulf Coast.

HETEROHELIX STRIATA (Ehrenberg)

Pl. V, fig. 10

Textularia striata EHRENBERG, 1840, K. Akad. Wiss. Berlin, Physik. Abh., (Jahrg. 1838), p. 135, pl. 4, figs. 1α, 1α', 2α, 3α, 9α.
Gümbelina striata (Ehrenberg). EGGER *(partim),* 1899, K. Bayer. Akad. Wiss., Math.-naturh., Abt., Abh., Kl. 2, vol. 21, pt. 1, p. 33, pl. 14, figs. 37-39 (*not* figs. 5-7, 10, 11).
Gümbelina striata (Ehrenberg) Egger. CUSHMAN, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 104, pl. 45, figs. 4, 5. (synonymy).
Gümbelina striata (Ehrenberg) Egger. CUSHMAN, 1949, U. S. Geol. Surv., Prof. Paper 221-A, p. 7, pl. 3, fig. 24.
Gümbelina striata (Ehrenberg). FRIZZELL, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 110, pl. 15, figs. 39, 40.

Diagnosis: Test elongate, tapering, greatest breadth near apertural end, periphery lobate; chambers distinctly inflated, subspherical; sutures distinct, strongly depressed; wall calcareous; surface ornamented with distinct and fine longitudinal costae, becoming less distinct in later chambers which bear fine pits in longitudinal alignment, final chambers smooth; aperture large, open, at the inner margin of the apertural face.

Figured specimen: USNM 639538, length 0.425 mm, breadth 0.26 mm, collected 8 feet below the top. Compared with plesiotypes in USNM: agrees favorably.

Discussion: This species is widely distributed in the Austin, Taylor, and Navarro strata of the Gulf Coast.

HETEROHELIX GLOBULOSA (Ehrenberg)

Pl. V, fig. 11

Textularia globulosa EHRENBERG, 1840, K. Akad. Wiss. Berlin, Physik. Abh., (Jahrg. 1838), p. 135, pl. 4, figs. 2β, 4β, 5β, 7β, 8β.
Textilaria globifera REUSS *(partim),* 1860, Akad. Wiss. Wien, Math.-naturw. Kl., Sitzb., vol. 40, p. 232, pl. 13, figs. 7, 8. (*not* synonymy).
Gümbelina globulosa (Ehrenberg). EGGER, 1899, K. Bayer. Akad. Wiss., Math.-naturw., Abt., Abh., Kl. 2, vol. 21, pt. 1, p. 32, pl. 14, fig. 43.
Gümbelina globifera (Reuss). EGGER, 1899, K. Bayer. Akad. Wiss., Math.-naturw., Abt., Abh., Kl. 2, vol. 21, pt. 1, p. 33, pl. 14, figs. 35, 36, 53-55.
Gümbelina pupa (Reuss). WHITE (not *Textilaria pupa* Reuss), 1929, Jour. Paleontology, p. 38, pl. 4, figs. 11a, b.
Gümbelina globulosa (Ehrenberg) Egger. CUSHMAN, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 105, pl. 45, figs. 9-15. (synonymy).
Gümbelina globulosa (Ehrenberg). FRIZZELL, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 109, pl. 15, figs. 24-27.
Heterohelix globulosa (Ehrenberg). MONTANARO GALLITELLI, 1957, U. S. Natl. Mus., Bull. 215, p. 137, pl. 31, figs. 12-15.

Diagnosis: Test tapering, greatest breadth near the apertural end, base subacute, periphery distinctly lobate; chambers inflated, nearly spherical, increasing rapidly and regularly in size as added; sutures distinct, depressed; wall calcareous, finely perforate; surface smooth; aperture broad, low, with a slightly thickened rim above.

Figured specimen: USNM 639539, length 0.30 mm, breadth 0.225 mm, collected 8 feet

below the top. Compared with plesiotypes in USNM: agrees favorably.

Discussion: This species is common in the Gulf Coast Taylor and Navarro strata. It is distinguished by its small size and regular form.

Genus Pseudoguembelina Bronnimann and Brown, 1953

Pseudoguembelina Bronnimann and Brown, 1953, Cushman Foundation Foram. Res., Contr., vol. 4, pt. 4, p. 150.

Type species: Gümbelina excolata Cushman, 1926. Original designation. *Gender:* feminine.

Pseudoguembelina costulata (Cushman)

Pl. V, fig. 12

Gümbelina costulata Cushman, 1938, Cushman Lab. Foram. Res., Contr., vol. 14, pt. 1, p. 16, pl. 3, figs. 7-9.
Gümbelina costulata Cushman. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 108, pl. 46, figs. 10-12. (synonymy).
Gümbelina costulata Cushman. Cushman, 1949, U. S. Geol. Surv., Prof. Paper 221-A, p. 7, pl. 3, fig. 25.
Gümbelina costulata Cushman. Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 108, pl. 15, figs. 17-19.
Pseudoguembelina costulata (Cushman). Montanaro Gallitelli, 1957, U. S. Natl. Mus., Bull. 215, p. 139, pl. 31, figs. 21, 22.

Diagnosis: Test biserial, tapering, compressed, greatest breadth near the apertural end, base acute or pointed, earlier periphery slightly keeled, later slightly indented; chambers slightly inflated, reniform, generally broader than high, final chambers higher peripherally and laterally compressed near the aperture; earlier sutures slightly limbate, later depressed and slightly curved; wall calcareous; surface ornamented with fine, longitudinal costae, becoming curved and subparallel to the periphery in the adult; aperture arched, sinuous, extending downward into tubuliform lateral lobes in each mature chamber producing accessory apertures which may be covered by tiny flaps.

Figured specimen: USNM 639540, length 0.40 mm, breadth 0.26 mm, collected 8 feet below the top. Compared with the holotype and paratypes in USNM: agrees, but larger than the holotype.

Discussion: This species is reported from the Taylor and Navarro of Texas, Arkansas, Mississippi, Alabama, and Tennessee.

Genus Tubitextularia Sulc, 1929

Tubitextularia Sulc, 1929, Vestnìk. Stàt. Geol. Českosl. Rep., vol. 5, p. 148.

Type species: Pseudotextularia bohemica Sulc, 1929. *Gender*: feminine.

Discussion: Rectogümbelina Cushman, 1932, is a junior synonym of *Tubitextularia* Sulc (Glaessner, 1936; Montanaro Gallitelli, 1957).

Tubitextularia cretacea (Cushman)

Rectogümbelina cretacea Cushman, 1932, Cushman Lab. Foram. Res., Contr., vol. 8, pt. 1, p. 6, pl. 1, figs. 11, 12.
Rectogümbelina cretacea Cushman. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 110, pl. 47, figs. 2, 3. (synonymy).
Tubitextularia cretacea (Cushman). Montanaro Gallitelli, 1957, U. S. Natl. Mus., Bull. 215, p. 143.

Discussion: This species, described from the Arkadelphia (questionably) by Cushman (1932, 1946), was not identified from the samples studied by the writer. The holotype and paratypes in the USNM were examined.

Genus Pseudotextularia Rzehak, 1891

Pseudotextularia Rzehak *(partim),* 1891, Naturh. Hofmuseums, Wien, Ann., vol. 6, no. 1, p. 2.

Type species: Cuneolina elegans Rzehak, 1891. Subsequent monotypy, Rzehak, 1891. *Gender:* feminine.

Pseudotextularia elegans (Rzehak)

Pl. V, fig. 17

Cuneolina elegans Rzehak *(partim),* 1891, Naturh. Hofmuseums, Wien, Ann., vol. 6, no. 1, p. 2.
Pseudotextularia varians Rzehak *(partim),* 1895, Naturh. Hofmuseums, Wien, Ann., vol. 10, pt. 2, p. 217, pl. 7, fig. 1 (*not* figs. 2, 3).
not *Gümbelina fructicosa* Egger, 1900, K. Bayer. Akad. Wiss., Math-naturh., Abt., Abh., Kl. 2, vol. 21, p. 35, pl. 14, figs. 8, 9.
Textularia taylorensis Dumble and Applin, 1924, Pan-American Geol., vol. 41, p. 342 [*nomen nudum*].
Pseudotextularia elegans Rzehak var. *varians* Rzehak. Glaessner *(partim),* 1936, Prob. Paleontology, Univ. Moscow Paleont. Lab., vol. 1, p. 101.
not *Pseudotextularia varians* Rzehak. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 110, pl. 47, figs. 4-7.
not *Pseudotextularia varians* Rzehak. Cushman, 1949, U. S. Geol. Surv., Prof. Paper 221-A, p. 8, pl. 3, fig. 26.
not *Pseudotextularia elegans* (Rzehak). Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 111, pl. 16, figs. 5-7.

Pseudotextularia elegans (Rzehak). Montanaro Gallitelli, 1957, U. S. Natl. Mus., Bull. 215, p. 138, pl. 33, figs. 6a-c.

Diagnosis: Test free, biserial, cuneiform; chambers increase rapidly in size as added, later chambers increase rapidly in thickness and become compressed laterally so that the original ratio of breadth to thickness is inverted, reaching an extreme of 1:4; sutures distinct; wall calcareous; surface ornamented by longitudinal costae; aperture an elongate slit at the base of the apertural face of the last-formed chamber.

Figured specimen: USNM 539541, length 0.44 mm, breadth 0.25 mm, thickness 0.30 mm, collected 8 feet below the top of the Arkadelphia.

Discussion: Pseudotextularia Rzehak properly includes only forms which are exclusively biserial. Many specimens with proliferation of chambers in the adult stage have been referred to this genus and to the species *Pseudotextularia elegans* (Rzehak), but should be placed in *Racemiguembelina* Montanaro Gallitelli, 1957. This is the first record of the exclusively biserial form from the Arkadelphia marl.

Genus Racemiguembelina Montanaro Gallitelli, 1957

Racemiguembelina Montanaro Gallitelli, 1957, U. S. Natl. Mus., Bull. 215, p. 142.

Type species: Gümbelina fructicosa Egger, 1900. Original designation. *Gender:* feminine.

Racemiguembelina fructicosa (Egger)

Pl. V, fig. 14

Cuneolina elegans Rzehak *(partim),* 1891, Naturh. Hofmuseums, Wien, Ann., vol. 6, no. 1, p. 2.

Pseudotextularia varians Rzehak *(partim),* 1895, Naturh. Hofmuseums, Wien, Ann., vol. 10, pt. 2, p. 217, pl. 7, figs. 2, 3 (*not* fig. 1).

Gümbelina fructicosa Egger, 1900, K. Bayer. Akad. Wiss., Math.-naturh., Abt., Abh., Kl. 2, vol. 21, p. 35, pl. 14, figs. 8, 9.

Pseudotextularia elegans Rzehak var. *varians* Rzehak. Glaessner *(partim),* 1936, Prob. Paleontology, Univ. Moscow Paleont. Lab., vol. 1, p. 101.

Pseudotextularia varians Rzehak. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 110, pl. 47, figs. 4-7. (synonymy).

Planoglobulina acervulinoides (Egger) Cushman. Cushman *(partim),* 1946, U. S. Geol. Surv., Prof. Paper 206, p. 111, pl. 47, figs. 15a, b (*not* 12-14).

Pseudotextularia varians Rzehak. Cushman, 1949, U. S. Geol. Surv., Prof. Paper 221-A, p. 8, pl. 3, fig. 26.

Pseudotextularia elegans (Rzehak). Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 111, pl. 16, figs. 5-7.

Racemiguembelina fructicosa (Egger). Montanaro Gallitelli, 1957, U. S. Natl. Mus., Bull. 215, p. 142, pl. 32, figs. 14, 15.

Diagnosis: Test free, biserial, somewhat compressed, increasing regularly and equally in thickness and breadth, finally proliferated with additional globular chambers, the last of which form a crown at the top of the test; sutures distinct, depressed; wall calcareous; surface longitudinally costate; aperture a series of arcuate, basal openings.

Figured specimen: USNM 639542, length 0.57 mm, breadth 0.35 mm, collected 10 feet below the top. Numerous plesiotypes of "*Pseudotextularia varians* Rzehak" in the USNM are conspecific.

Discussion: Cushman reported (1949) "*Pseudotextularia varians* Rzehak" from the Arkadelphia and illustrated a specimen with proliferation of the final chambers. Cushman's specimen must be placed in *Racemiguembelina* Montanaro Gallitelli, 1957.

Genus Planoglobulina Cushman, 1927

Planoglobulina Cushman, 1927, Cushman Lab. Foram. Res., Contr., vol. 2, pt. 4, p. 77.

Type species: Gümbelina acervulinoides Egger, 1900. Original designation. *Gender:* feminine.

Planoglobulina acervulinoides (Egger)

Gümbelina acervulinoides Egger, 1900, K. Bayer. Akad. Wiss., Math.-naturh., Abt., Abh., Kl. 2, vol. 21, p. 36, pl. 14, figs. 17, 18, 20-22.

Pseudotextularia acervulinoides Cushman. Cushman, 1926, Wash. Acad. Sci., Jour., vol. 15, p. 134.

Planoglobulina acervulinoides (Egger) Cushman. Cushman, 1927, Cushman Lab. Foram. Res., Contr., vol. 3, pt. 1, pl. 13, fig. 5.

Planoglobulina acervulinoides (Egger) Cushman. Cushman *(partim),* 1946, U. S. Geol. Surv., Prof. Paper 206, p. 111, pl. 47, figs. 12-14 (*not* fig. 15). (synonymy, *partim*).

[?]*Planoglobulina acervulinoides* (Egger) Cushman. Cushman, 1949, U. S. Geol. Surv., Prof. Paper 221-A, p. 8, pl. 3, fig. 27.

Planoglobulina acervulinoides (Egger). Montanaro Gallitelli, 1957, U. S. Natl. Mus., Bull. 215, p. 141.

Discussion: This species, reported by Cushman (1949) from the Arkadelphia, was not recovered from the samples studied by the writer. Forms included in this species by Cushman are now placed in *Racemi-*

guembelina fructicosa (Egger). Thus, it is doubtful if *Planoglobulina acervulinoides* (Egger) has been found in the Arkadelphia.

Planoglobulina carseyae (Plummer)

Pl. V, fig. 18

Textularia globulosa Ehrenberg. Carsey (*not* Ehrenberg), 1926, Texas Bur. Econ. Geol., Univ. Texas, Bull. 2612, p. 25, pl. 5, figs. 2a, b.
Pseudotextularia a, d Plummer, 1927, Texas Bur. Econ. Geol., Univ. Texas, Bull. 2644, p. 172, pl. 2, figs. 1, 4.
Ventilabrella carseyae Plummer, 1931, Texas Bur. Econ. Geol., Univ. Texas, Bull. 3101, p. 178, pl. 9, figs. 7-10.
Ventilabrella plummerae Sandidge, 1932, Amer. Midland Nat., vol. 13, p. 195, pl. 19, figs. 5, 6.
Ventilabrella carseyae Plummer. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 112, pl. 48, figs. 1-5. (synonymy).
not *Ventilabrella carseyae* Plummer. Cushman, 1949, U. S. Geol. Surv., Prof. Paper 221-A, p. 8, pl. 3, fig. 28.
Gümbelina carseyae (Plummer). Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 108, pl. 15, figs. 14-16.
Planoglobulina carseyae (Plummer). Montanaro Gallitelli, 1957, U. S. Natl. Mus., Bull. 215, p. 269, pl. 32, fig. 13.

Diagnosis: Test tapering, biserial, not compressed; chambers inflated, rapidly increasing in size as added; some specimens with three or more chambers in horizontal series in adult stage; sutures distinct, strongly depressed; wall calcareous, thin; surface longitudinally costate; aperture large, low, broad, at the inner margin of the apertural face, with a slight lip, and with a supplementary opening at the outer basal margin in the penultimate chamber.

Figured specimen: USNM 639543, length 0.375 mm, breadth 0.275 mm, collected 8 feet below the top. Compared with numerous identified specimens in USNM: compares favorably, but immature.

Discussion: This species is reported only from the Navarro strata and equivalents. The immature biserial stage differs clearly from *Pseudotextularia elegans* (Rzehak) which is laterally compressed.

Planoglobulina glabrata (Cushman)

Pl. V, fig. 15

Ventilabrella eggeri Cushman var. *glabrata* Cushman, 1938, Cushman Lab. Foram. Res., Contr., vol. 14, pt. 1, p. 26, pl. 4, figs. 15-17.
Ventilabrella eggeri Cushman var. *glabrata* Cushman. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 111, pl. 47, figs. 20-22.
Ventilabrella eggeri Cushman var *glabrata* Cushman. Frizzell 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 111, pl. 16, figs. 11, 12.
Planoglobulina glabrata (Cushman). Montanaro Gallitelli, 1957, U. S. Natl. Mus., Bull. 215, p. 141, pl. 32, figs. 10-12.

Diagnosis: Test free, strongly compressed, flabelliform; juvenarium resembles *Heterohelix globulosa* (Ehrenberg), adult chambers proliferated in the plane of biseriality; chambers numerous, globular; sutures distinct, depressed; wall calcareous, finely perforate; surface finely costate; aperture multiple, basal, in the final series of chambers.

Figured specimen: USNM 539544, length 0.44 mm, breadth 0.50 mm, collected 21 feet above the base of the Arkadelphia marl.

Discussion: The juvenarium of the form has been shown (Montanaro Gallitelli, 1957) to indicate the derivation of the genus from a *globulosa*-like *Heterohelix*. *Planoglobulina glabrata* (Cushman) is rare in the Arkadelphia. It is reported from the Austin, Taylor, and Navarro of the Gulf Coast.

Planoglobulina austinana (Cushman)

Pl. V, fig. 16

Ventilabrella eggeri Cushman. Carman (*not* Cushman), 1929, Jour. Paleontology, vol. 3, no. 3, p. 314, pl. 34, fig. 7.
Ventilabrella austinana Cushman, 1938, Cushman Lab. Foram. Res., Contr., vol. 14, pt. 1, p. 26, pl. 4, figs. 19a, b.
Ventilabrella austinana Cushman. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 111, pl. 47, fig. 16. (synonymy).
Ventilabrella austiniana Cushman. Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 111, pl. 16, figs. 9a, b.

Diagnosis: Test free, strongly compressed, tapering; juvenarium biserial, chambers numerous; adult chambers globular, typically consisting of only two rows of chambers proliferated in the plane of biseriality; sutures distinct, depressed; wall calcareous, finely perforate; surface smooth; aperture multiple, basal.

Figured specimen: USNM 639545, length 0.50 mm, breadth 0.41 mm, collected 8 feet below the top. Compared with the holotype and paratypes in USNM: agrees.

Discussion: This species is distinguished by the evenly tapered test and smooth surface from *P. glabrata* (Cushman) which is flared laterally. This is the first record from the Navarro. It has been reported from the Eagle Ford, Austin, and Taylor of Texas and the lower Selma chalk (Austin) of Mississippi.

Family GLOBOTRUNCANIDAE Brotzen, 1942

Genus GLOBOTRUNCANA Cushman, 1927

Globotruncana CUSHMAN, 1927, Cushman Lab. Foram. Res., Contr., vol. 3, pt. 1, p. 91.

Type species: Pulvinulina arca Cushman, 1926. Original designation and monotypy. *Gender:* feminine.

GLOBOTRUNCANA ARCA (Cushman)

?Pulvinulina rosetta DUMBLE and APPLIN, 1924, Pan-American Geol., vol. 41, p. 342 [*nomen nudum*].
Pulvinulina arca CUSHMAN, 1926, Cushman Lab. Foram. Res., Contr., vol. 2, pt. 1, p. 23, pl. 3, figs. 1a-c.
Globigerina rosetta CARSEY, 1926, Texas Bur. Econ. Geol., Univ. Texas, Bull. 2612, p. 44, pl. 5, figs. 3a-c.
Globotruncana arca (Cushman). CUSHMAN, 1927, Cushman Lab. Foram. Res., Contr., vol. 3, pt. 1, p. 91, pl. 19, figs. 11a-c.
Globotruncana arca (Cushman). PLUMMER *(partim),* 1931, Texas Bur. Econ. Geol., Univ. Texas, Bull. 3101, p. 195, pl. 13, figs. 9, 11 [holotype of *Globigerina rosetta* Carsey], (*not* figs. 7, 8).
Globotruncana arca (Cushman) Cushman. CUSHMAN, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 150, pl. 62, figs. 4, 5. (synonymy).
Globotruncana arca (Cushman) Cushman. CUSHMAN, 1949, U. S. Geol. Surv., Prof. Paper 221-A, p. 10, pl. 4, figs. 22, 23.
Globotruncana arca (Cushman). FRIZZELL, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 128, pl. 20, figs. 22a-c.
Globotruncana arca (Cushman). BOLLI, LOEBLICH, and TAPPAN, 1957, U. S. Natl. Mus., Bull. 215, p. 44, pl. 11, figs. 6-11c.
Globotruncana arca (Cushman). BARR, 1962, Paleontology, vol. 4, pt. 4, p. 567, pl. 69, figs. 8a-c.

Discussion: This species, reported by Cushman (1949) from the Arkadelphia, was nct identified in the samples studied by the writer. Several hundred Arkadelphia specimens of *Globotruncana* were examined but none could be placed in *Globotruncana arca* (Cushman). The holotype in the USNM was examined. Cushman's figures (1949) do not appear typical for the species. It is doubtful that it is present in the Arkadelphia marl.

GLOBOTRUNCANA CANALICULATA (Reuss)

Rosalina canaliculata REUSS, 1854, Akad. Wiss. Wien, Math.-naturw. Kl., Denkschr., vol. 7, p. 70, pl. 26, figs. 4a, b.
Globigerina canaliculata (Reuss). EGGER, 1900, K. Bayer. Akad. Wiss., Math.-naturh., Abt., Abh., Kl. 2, vol. 21, pt. 1, p. 172, pl. 21, figs. 15-17, 24-26.
Globotruncana canaliculata (Reuss). CUSHMAN, 1927, Cushman Lab. Foram. Res., Contr., vol. 3, pt. 2, p. 116, pl. 23, figs. 11a-c.
Globotruncana canaliculata (Reuss) Cushman. CUSHMAN, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 149, pl. 61, figs. 17, 18. (synonymy).
[?] *Globotruncana canaliculata* (Reuss) Cushman. CUSHMAN, 1949, U. S. Geol. Surv., Prof. Paper 221-A, p. 10, pl. 4, figs. 20, 21.
Globotruncana canaliculata (Reuss). FRIZZELL, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 128, pl. 20, figs. 21a-c.

Discussion: This species, reported by Cushman (1949) from the Arkadelphia, was not identified in the samples studied by the writer. Several hundred Arkadelphia specimens of *Globotruncana* were examined but none could be placed in *Globotruncana canaliculata* (Reuss). Cushman's figures (1949) do not appear to have the characteristic canaliculate periphery.

GLOBOTRUNCANA CRETACEA Cushman

Pl. VI, figs. 19, 20

Globotruncana arca (Cushman). CUSHMAN (not *Pulvinulina arca* Cushman), 1931, Tennessee Div. Geol., Bull. 41, p. 59, pl. 11, figs. 6a, b.
Globotruncana arca (Cushman). PLUMMER (*partim;* not *Pulvinulina arca* Cushman), 1931, Texas Bur. Econ. Geol., Univ. Texas, Bull. 3101, p. 230, pl. 13, figs. 7, 8, (*not* 9, 11).
Globotruncana cretacea CUSHMAN, 1938, Cushman Lab. Foram. Res., Contr., vol. 14, pt. 3, p. 67, pl. 11, figs. 6a-c.
Globotruncana cretacea CUSHMAN, 1939, Cushman Lab. Foram. Res., Contr., vol. 15, pt. 4, p. 92, pl. 16, figs. 8a-c [erroneously republished as new].
Globotruncana cretacea Cushman. CUSHMAN, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 151, pl. 62, figs. 7a-c. (synonymy).
Globotruncana cretacea Cushman. CUSHMAN, 1949, U. S. Geol. Surv., Prof. Paper 221-A, p. 10, pl. 4, figs. 24, 25.
Globotruncana cretacea Cushman. FRIZZELL, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 128, pl. 20, figs. 25a-c.

Diagnosis: Test free, biconvex, dorsal surface somewhat flattened, or even slightly concave in some specimens, umbilical surface strongly convex, periphery with a single keel, somewhat lobulate; chambers distinct, the last-formed nearly semi-circular in dorsal view, slightly overlapping, ventrally inflated; dorsal sutures quite distinct, strongly curved, raised, conspicuously beaded, ventral sutures depressed; wall calcareous, finely perforate; surface smooth except for the beaded peripheral ridge and dorsal sutures; aperture ventral, opening into the umbilical cavity which is covered by a thin, plate-like tegilla in well-preserved specimens.

Figured specimen: USNM 639546, maximum diameter 0.52 mm, collected 8 feet below the top. Compared with the holotype in USNM: agrees perfectly.

Discussion: This species is common to abundant in numerous localities in the Austin, Taylor, and Navarro of the Gulf Coast. It is abundant in the Arkadelphia marl. The species is somewhat varied and it is probable that the specimens identified as *Globotruncana arca* (Cushman) and *G. canaliculata* (Reuss) by Cushman are conspecific with *G. cretacea* Cushman.

Globotruncana gansseri Bolli

Pl. VI, figs. 21, 22

Globotruncana gansseri Bolli, 1950, Cushman Foundation Foram. Res., Contr., vol. 1, pts. 3-4, p. 87. [*nomen nudum*].
Globotruncana gansseri Bolli, 1951, Jour. Paleontology, vol. 25, no. 2, p. 196, pl. 35, figs. 1-3.
Globotruncana gansseri Bolli. Bolli, Loeblich, and Tappan, 1957, U. S. Natl. Mus., Bull. 215, p. 54 (synonymy), p. 56.

Diagnosis: Test free, trochoid, planoconvex, dorsal surface flattened, ventral surface strongly convex, a distinct lobulate marginal keel separates the two surfaces, test quadrangular in transverse section with a prominent, deep umbilicus; chambers distinct, overlapping, ventrally inflated, typically 5 to a volution, the last-formed and largest chamber subcircular in dorsal view; dorsal sutures quite distinct, curved, raised, and finely beaded, ventral sutures depressed; wall calcareous, finely perforate; surface smooth to finely hispid or rugulose, particularly on the ventral surface; aperture ventral, quite large, opening into the prominent umbilical cavity which is covered by a thin tegilla in well preserved specimens.

Figured specimen: USNM 639547, maximum diameter 0.46 mm, thickness 0.275 mm, collected 16 feet above the base. Compared with a topotype (Cushman Collection 59687) in the USNM: agrees exactly.

Discussion: This form is common in the Arkadelphia and constitutes an excellent marker fossil for the Navarro and equivalents (Maestrichtian).

Family Globorotaliidae Cushman, 1927

Subfamily Globorotaliinae Cushman, 1927

Genus Globorotalia Cushman, 1927

Globorotalia Cushman, 1927, Cushman Lab. Foram. Res., Contr., vol. 3, pt. 1, p. 91.

Type species: Pulvinulina menardii var. *tumida* H. B. Brady, 1877. Original designation and monotypy [cited as *Pulvinulina tumida* H. B. Brady, 1884]. *Gender:* feminine.

"Globorotalia membranacea (Ehrenberg)"

Globorotalia membranacea (Ehrenberg) White. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 152, pl. 63, figs. 5a, b.
Globorotalia membranacea (Ehrenberg) White. Cushman, 1949, U. S. Geol. Surv., Prof. Paper 221-A, p. 10.
Globorotalia membranacea (Ehrenberg). Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 130, pl. 20, figs. 30a, b.

Discussion: "*Globorotalia membranacea* (Ehrenberg)" was reported by Cushman from the Corsicana marl of Texas (1946) and the Arkadelphia marl (1949). His figures are globorotaliform but the apertural view is not shown and the presence of an apertural lip is not noted in his descriptions. Cushman recorded a single specimen from the Arkadelphia marl in 1949.

Globorotalia was not recovered from the zonal samples studied by the writer, but a single specimen was found in a bulk surface sample from the upper Arkadelphia. This form has a rounded periphery and compares quite favorably with Cushman's illustrations. As recent studies (Bolli, Loeblich, and Tappan, 1957) have shown *Globorotalia* to be confined to the post-Cretaceous, it is likely that both this specimen and Cushman's single specimen are contamination due to surface wash from the overlying Midway formation where unkeeled *Globorotalia* is known to occur.

Ehrenberg illustrated but did not describe *Globorotalia membranacea* and the depository of the types is not given. The only available evidence, Ehrenberg's figures, could place the form in almost any coiled genus, and *G. membranacea* is therefore unrecognizable (Loeblich and Tappan, 1957).

Family Globigerinidae Carpenter, Parker and Jones, 1862

Subfamily Globigerininae Carpenter, Parker and Jones, 1862

Genus Rugoglobigerina Bronnimann, 1952

Rugoglobigerina Bronnimann, 1952, Bull. Amer. Paleontology, vol. 34, no. 140, p. 16.

Type species: Globigerina rugosa Plummer, 1927. Original designation. *Gender:* feminine.

Rugoglobigerina rugosa (Plummer)

Pl. VI, fig. 18

Globigerina cretacea d'Orbigny. Carsey (*not* d'Orbigny), 1926, Texas Bur. Econ. Geol., Univ. Texas, Bull. 2612, p. 43, pl. 5, figs. 5a, b.
Globigerina rugosa Plummer, 1927, Texas Bur. Econ. Geol., Univ. Texas, Bull. 2644, p. 38, pl. 2, figs. 10a-d.
Globigerina rugosa Plummer. Plummer, 1931, Texas Bur. Econ. Geol., Univ. Texas, Bull, 3101, p. 194.
Rugoglobigerina rugosa (Plummer). Bronnimann, 1952, Bull. Amer. Paleontology, vol. 34, no. 140, p. 16.
Globigerina rugosa Plummer. Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 127, pl. 20, figs. 3-6.
Rugoglobigerina rugosa (Plummer). Bolli, Loeblich, and Tappan, 1957, U. S. Natl. Mus., Bull. 215, p. 43, pl. 11, figs. 2a-c.

Diagnosis: Test free, minute, trochospiral, biconvex, umbilicate, periphery rounded; chambers nearly spherical, five in the last volution, enlarging rapidly as added; sutures depressed, radial; wall calcareous, perforate; surface onamented with numerous large pustules which may coalesce into distinct ridges radiating from the midpoint of each chamber on the periphery; primary apertures interiomarginal, umbilical, in well preserved specimens covered by tegilla perforated by the accessory infralaminal and intralaminal apertures which are the only openings to the exterior.

Figured specimen: USNM 639548, maximum diameter 0.39 mm, collected 8 feet below the top. Compared with the autotypes in USNM: agrees.

Discussion: This small distinctly ornamented form is an index fossil for the Navarro strata of the Gulf Coast.

Superfamily Orbitoidacea Schwager, 1876

Family Anomalinidae Cushman, 1927

Genus Anomalina d'Orbigny, 1826

Anomalina d'Orbigny, 1826, Ann. Sci. Nat., sér. 1, vol. 7, p. 282.
Anomalina d'Orbigny, emend. Marie, 1941, Paris, Mus. Natl. Hist. Nat., Mém., new ser., vol. 12, fasc. 1, pp. 243, 257.

Type species: Anomalina punctulata d'Orbigny, 1826. First species, designated by Cushman, 1915. *Gender:* feminine.

Anomalina nelsoni W. Berry

Anomalina nelsoni W. Berry, *in* Berry and Kelley, 1929, U. S. Natl. Mus., Proc., vol. 76, art. 19, p. 14, pl. 2, figs. 19-21.
Anomalina involuta (Reuss). Cushman (not *Rotalina involuta* Reuss, 1851; not *Rotalina involuta* Terquem, 1882), 1931, Tennessee Div. Geol., Bull. 41, p. 60, pl. 12, figs. 1a-c.
Cibicides nelsoni Plummer, 1936, Texas Bur. Econ. Geol., Univ. Texas, Bull. 3501, p. 288, pl. 5, figs. 1-6.
Valvulineria nelsoni (Plummer). Jennings, 1936, Bull. Amer. Paleontology, vol. 23, no. 78, p. 32, pl. 4, figs. 1a, b.
Anomalina nelsoni W. Berry. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 154, pl. 63, figs. 8, 9. (synonymy).

Discussion: This species, reported by Cushman (1946) from the Arkadelphia, was not identified from the samples studied by the writer. The holotype in the USNM was examined.

Anomalina pseudopapillosa Carsey

Pl. VI, fig. 23

Anomalina pseudopapillosa Carsey, 1926, Texas Bur. Econ. Geol., Univ. Texas, Bull. 2612, p. 47, pl. 1, figs. 6a, b.
Anomalina navarroensis Plummer, 1927, Texas Bur. Econ. Geol., Univ. Texas, Bull. 2644, p. 38, pl. 2, figs. 6a-c.
Anomalina pseudopapillosa Carsey. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 154, pl. 64, figs. 1a-c. (synonymy).
Anomalina pseudopapillosa Carsey. Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 131, pl. 21, figs. 6a-c.

Diagnosis: Test free, trochospiral, subequally biconvex, both sides nearly involute, periphery rounded but somewhat contracted; chambers simple, numerous, 12 or more in the adult volution, slightly inflated, uniform, increasing gradually in size as added; sutures distinct, strongly limbate, somewhat raised, terminating inwardly in distinctive bead-like prominences; wall calcareous, coarsely perforate; surface appears granular; aperture nearly equatorial, basal in the apertural face, with a slight lip.

Figured specimen: USNM 639549, maximum diameter 0.288 mm, collected 8 feet below the top. Compared with numerous identified specimens in USNM: agrees.

Discussion: This small, distinctive species is an excellent marker for the Navarro strata. It has been reported from numerous localities in Texas, Arkansas, Mississippi, and Alabama.

Genus Anomalinoides Brotzen, 1942

Anomalinoides Brotzen, 1942, Sveriges Geol. Undersökning, Afh., ser. C, no. 451, vol. 36, pt. 8, p. 23.

Type species: Anomalinoides plummerae Brotzen, 1942, = *Anomalina pinguis* Jennings, 1936. Original designation. *Gender:* masculine.

Anomalinoides pinguis (Jennings)

Pl. VI, fig. 24

Anomalina grosserugosa Gümbel. Carsey (not *Truncatulina grosserugosa* Gümbel), 1926, Texas Bur. Econ. Geol., Univ. Texas, Bull. 2612, p. 46, pl. 3, figs. 3a, b.
Anomalina pinguis Jennings, 1936, Bull. Amer. Paleontology, vol. 23, no. 78, p. 37, pl. 5, fig. 1.
Anomalinoides plummerae Brotzen, 1942, Sveriges Geol. Undersökning, Afh., ser. C, no. 451, vol. 36, pt. 8, p. 23.
Anomalina pinguis Jennings. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 156. (synonymy).
Anomalina pinguis Jennings. Cushman, 1949, U. S. Geol. Surv., Prof. Paper 221-A, p. 10, pl. 4, figs. 29, 30.
Anomalinoides pinquis (Jennings). Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 131, pl. 21, figs. 8a-c. (synonymy).

Diagnosis: Test free, trochospiral, subequally biconvex, ventral side involute and slightly more convex, periphery broadly rounded; chambers simple, 8 to 9 in the adult volution, distinctly inflated; sutures distinct, limbate in juvenarium, depressed in the adult volution, slightly curved; aperture basal, nearly equatorial, extending to the dorsal side along the inner margin of the last-formed chamber.

Figured specimen: USNM 639550, maximum diameter 0.288 mm, collected 8 feet below the top. Compared with plesiotypes in USNM: compares favorably with those from the Arkadelphia, but those from the Pecan Gap chalk are much more inflated.

Discussion: This species is reported from the Corsicana marl and Taylor marl of Texas and from the Navesink marl and Mt. Laurel sand of New Jersey.

Genus Planulina d'Orbigny, 1826

Planulina d'Orbigny, 1826, Ann. Sci. Nat., vol. 7, p. 280.

Type species: Planulina ariminensis d'Orbigny, 1826. First species, designated by Galloway and Wissler, 1927. *Gender:* feminine.

Planulina correcta (Carsey)

Pl. VI, figs. 25, 26

Discorbis correcta Carsey, 1926, Texas Bur. Econ. Geol., Univ. Texas, Bull. 2612, p. 45, pl. 3, figs. 5a, b.
Planulina correcta (Carsey). Cushman, 1940, Cushman Lab. Foram. Res., Contr., vol. 16, pt. 2, p. 36, pl. 6, figs. 11a-c.
Planulina correcta (Carsey) Cushman. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 158, pl. 65, figs. 1a-c. (synonymy).
Planulina correcta (Carsey). Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 132, pl. 21, figs. 10a-c.

Diagnosis: Test free, trochospiral, strongly compressed, periphery somewhat rounded, lobulate, dorsal side gently convex and evolute, ventral side strongly flattened to concave and nearly involute; chambers distinct, slightly inflated, 5 to 9 in the adult volution, earlier chambers low and broad, becoming abruptly higher and increasingly larger in the adult volution; sutures distinct, earlier ones limbate and slightly raised, later ones simple, slightly depressed and curved; wall calcareous, distinctly perforate; surface smooth; aperture a low elongate slit with a slight lip.

Figured specimen: USNM 639551, maximum diameter 0.60 mm, collected 8 feet below the top. Compared with identified specimens in USNM: agrees.

Discussion: This characteristic species is restricted to the Navarro strata of Texas, Arkansas, Mississippi, and Alabama.

Superfamily Cassidulinacea d'Orbigny, 1839

Family Caucasinidae Bykova, 1959

Subfamily Fursenkoininae Loeblich and Tappan, 1961

Genus Fursenkoina Loeblich and Tappan, 1961

Virgulina d'Orbigny (not *Virgulina* Bory de St. Vincent, 1823), 1826, Ann. Sci. Nat., vol. 7, p. 267.
Fursenkoina Loeblich and Tappan, 1961, Jour. Paleontology, vol. 35, no. 2, p. 314.

Type species: Virgulina squammosa d'Orbigny, 1826. Original designation. *Gender:* feminine.

Fursenkoina navarroana (Cushman)

Pl. V, fig. 25

Virgulina navarroana Cushman, 1933, Cushman Lab. Foram. Res., Contr., vol. 9, pt. 3, p. 63, pl. 7, figs. 9, 10.
Virgulina navarroana Cushman. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 126, pl. 53, figs. 5-7. (synonymy).
Virgulina navarroana Cushman. Frizzell, 1954,

Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 117, pl. 17, figs. 17, 18.

Diagnosis: Test elongate, tapering, maximum breadth near the apertural end, periphery rounded, initial end pointed; chambers biserial, distinct, slightly inflated, twisted in a gentle spiral about the elongate axis, the last-formed somewhat more elongate than the earlier ones; sutures distinct, slightly depressed; wall calcareous, perforate; surface smooth; aperture elliptical, loop-shaped, with a slight rim.

Figured specimen: USNM 639552, length 0.34 mm, breadth 0.125 mm, collected 8 feet below the top. Compared with the holotype and paratypes in USNM: compares favorably with the holotype and well within the range of the paratypes.

Discussion: This species was described from the Corsicana marl. It occurs also in the Kemp clay and rarely in the Arkadelphia marl.

Family Pleurostomellidae Reuss, 1860

Subfamily Pleurostomellinae Reuss, 1860

Genus Stilostomella Guppy, 1894

Stilostomella Guppy, 1894, Zool. Soc. London, Proc., p. 649.
Ellipsonodosaria A. Silvestri, 1900, Accad. Sci. Lett. Arti Zelanti Acireale, Atti Rend., vol. 10, p. 4.
Siphonodosaria A. Silvestri, 1924, Soc. Geol. Ital., Boll., vol. 42, p. 18.

Type species: Stilostomella rugosa Guppy, 1894. Monotypic. *Gender:* feminine.

Stilostomella stephensoni (Cushman)

Pl. V. fig. 30

Ellipsonodosaria stephensoni Cushman, 1936, Cushman Lab. Foram. Res., Contr., vol. 12, pt. 3, p. 52, pl. 9, figs. 10-15.
Ellipsonodosaria stephensoni Cushman. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 134, pl. 56, figs. 2-7. (synonymy).
Ellipsonodosaria stephensoni Cushman. Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 121.
Stilostomella stephensoni (Cushman). Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 151, pl. 18, figs. 22, 23.

Diagnosis: Test elongate, tapering, slightly arcuate; chambers distinct, increasing in length and rather rapidly in diameter as added, adult chambers pyriform, somewhat inflated, broadest near the base; sutures distinct, depressed, somewhat limbate; wall calcareous, perforate; surface of early chambers smooth, later with a circlet of short, backwardly projecting spines near the base and a few, additional scattered spines on the upper part of the adult chamber; aperture crescentic with a distinct tooth and a slight lip, and surrounded by a distinct ring of shell material.

Figured specimen: USNM 639553, length of broken specimen 0.66 mm, maximum diameter 0.10 mm, collected 30 feet above the base. Compared with the holotype and paratypes in USNM: compares favorably.

Discussion: This species is reported from numerous upper Taylor and Navarro localities in Texas and Arkansas and from the lower Selma chalk (Austin) of Lee County, Mississippi.

Stilostomella stephensoni speciosa (Cushman)

Pl. V, fig. 31

Ellipsonodosaria stephensoni Cushman var. *speciosa* Cushman, 1938, Cushman Lab. Foram. Res., Contr., vol. 14, pt. 2, p. 47, pl. 8, fig. 3.
Ellipsonodosaria stephensoni Cushman var. *speciosa* Cushman. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 135, pl. 56, fig. 8. (synonymy).

Diagnosis: This form differs from the typical subspecies in the strongly pyriform adult chambers with spines distributed over the entire surface instead of confined to the basal margin.

Figured specimen: USNM 639554, length of broken specimen 0.75 mm, maximum diameter 0.125 mm, collected 30 feet above the base. Compared with the holotype and paratypes in USNM: agrees.

Discussion: This subspecies was described from Arkadelphia exposures 6 miles northwest of Hope, Arkansas. It has been reported only from the Arkadelphia and the Colon shale of Colombia.

Stilostomella alexanderi (Cushman)

Ellipsonodosaria alexanderi Cushman, 1936, Cushman Lab. Foram. Res., Contr., vol. 12, pt. 3, p. 52, pl. 9, figs. 6-9.
Ellipsonodosaria alexanderi Cushman. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 135, pl. 56, figs. 12-15.
Ellipsonodosaria alexanderi Cushman var. *alexanderi* Cushman. Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 121.
Stilostomella alexanderi (Cushman) var. *alexanderi* (Cushman). Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 151, pl. 18, figs. 13-14.

Diagnosis: Test elongate, straight or gently curved; microspheric test increasing rapidly in

diameter from the small proloculus, megalospheric test not tapering; chambers distinct, inflated, increasing gradually in length, adult chambers about twice as long as broad, pyriform; sutures distinct, strongly depressed; wall calcareous, perforate; surface ornamented with short, backwardly projecting spines, forming a single ring in the early microspheric chambers, numerous and irregularly distributed over the surface of the adult chambers; aperture a semi-circular opening with a single tooth, a distinct neck, and a slightly raised lip.

Discussion: The types of the species are from the Taylor marl in Delta County, Texas. This form is characteristic for the upper part of the Taylor marl.

STILOSTOMELLA ALEXANDERI IMPENSIA (Cushman)

Pl. V, fig. 32

Ellipsonodosaria alexanderi Cushman var. *impensia* CUSHMAN, 1938, Cushman Lab. Foram. Res., Contr., vol. 14, pt. 2, p. 48, pl. 8, figs. 4, 5.
Ellipsonodosaria alexanderi Cushman var. *impensia* Cushman. CUSHMAN, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 136, pl. 56, figs. 16-18. (synonymy).
Ellipsonodosaria alexanderi Cushman var. *impensia* Cushman. FRIZZELL, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 121.
Stilostomella alexanderi (Cushman) var. *impensia* (Cushman). FRIZZELL, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 151, pl. 18, figs. 15, 16.

Diagnosis: This subspecies differs from the typical form in the more fusiform adult chambers which are also more spinose, in the early microspheric chambers which bear numerous spines, in the greater number of spines which project backward less prominently, and in the larger size of the test.

Figured specimen: USNM 639555, length of incomplete specimen 1.59 mm, maximum diameter 0.25 mm, collected 30 feet above the base. Compared with the holotype and paratypes in USNM: agrees.

Discussion: The types of this subspecies are from the Corsicana marl, Limestone County, Texas. This form is characteristic of the upper Navarro strata of Texas, Arkansas, Mississippi, and Alabama. It is recorded also from the Mal Paso shale of Peru.

Family NONIONIDAE Schultze, 1854

Subfamily CHILOSTOMELLINAE Brady, 1881

Genus ALLOMORPHINA Reuss, 1850

Allomorphina REUSS, 1850, Akad. Wiss. Wien, Math.-naturw. Kl., Denkschr., vol. 1, p. 380.

Type species: Allomorphina trigona Reuss, 1850. Monotypic. *Gender:* feminine.

ALLOMORPHINA NAVARROANA Cushman

Pl. VI, fig. 15

Allomorphina navarroana CUSHMAN, 1936, Cushman Lab. Foram. Res., Contr., vol. 12, pt. 4, p. 73, pl. 13, figs. 1a-c.
Allomorphina navarroana Cushman. CUSHMAN, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 145, pl. 60, figs. 5a-c. (synonymy).
Allomorphina navarroana Cushman. CUSHMAN, 1949, U. S. Geol. Surv., Prof. Paper 221-A, p. 9, pl. 4, fig. 18.
Allomorphina navarroana Cushman. FRIZZELL, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 126, pl. 19, figs. 18a-c.

Diagnosis: Test small, a low trochospiral, slightly longer than broad, periphery rounded, three chambers to a volution in the juvenarium, tending to reduce to two in the adult test; chambers distinct, slightly inflated, the last two adult chambers form a large proportion of the test; sutures distinct, slightly depressed; wall calcareous, perforate; surface smooth; aperture low, elongate, interiomarginal, with a distinct overhanging lip.

Figured specimen: USNM 639556, length 0.26 mm, collected 8 feet below the top. Compared with the holotype and paratypes in USNM: compares favorably.

Discussion: This form is restricted to the Navarro strata of Arkansas and Texas. The types of the species are from the Corsicana marl, Navarro County, Texas.

Subfamily NONIONINAE Schultze, 1854

Genus NONIONELLA Cushman, 1926

Nonionella CUSHMAN, 1926, Cushman Lab. Foram. Res., Contr., vol. 2, pt. 3, p. 64.

Type species: Nonionella miocenica Cushman, 1926. Original designation. *Gender:* feminine.

NONIONELLA ROBUSTA Plummer

Pl. V, figs. 5, 6

Nonionina scapha Fichtel and Moll. CARSEY (not *Nautilus scapha* Fichtel and Moll), 1926, Texas Bur. Econ. Geol., Univ. Texas, Bull. 2612, p. 49, pl. 1, figs. 2a-c.
Nonionella robusta Plummer, 1931, Texas Bur. Econ. Geol., Univ. Texas, Bull. 3101, p. 175, pl. 14, figs. 12a-c.
Nonionella robusta Plummer. CUSHMAN, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 100, pl. 43, figs. 21-23. (synonymy).

Nonionella robusta Plummer. FRIZZELL, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 107, pl. 15, figs. 10a-c.

Diagnosis: Test small, moderately compressed, nearly equally biconvex, asymmetrically developed; umbilicate, dorsal umbilicus small, narrow, and shallowly depressed, exposing the inner volutions, ventral umbilicus irregularly filled by the lobate extensions of the chambers; periphery narrowly rounded and bluntly angular in the adult stage, only slightly lobate in the later portion of some tests, but generally an even curve; chambers distinct, about 8 in the final volution, lengthening rapidly, gently inflated in most specimens; sutures distinct, slightly depressed or flush, somewhat curved; wall calcareous, distinctly perforate; surface smooth; aperture a low slit, interiomarginal on the ventral side.

Figured specimen: USNM 639557, length 0.288 mm, breadth 0.25 mm, collected 8 feet below the top. Compared with plesiotypes in USNM: agrees.

Discussion: This species is reported from numerous localities in the Navarro of Texas, Arkansas, Mississippi, and Alabama.

NONIONELLA ANSATA Cushman

Pl. V, fig. 7

Nonionella ansata CUSHMAN, 1938, Cushman Lab. Foram. Res., Contr., vol. 14, pt. 2, p. 44, pl. 7, figs. 17a-c.
Nonionella ansata Cushman. CUSHMAN, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 101, pl. 44, figs. 1a-c.
Nonionella ansata Cushman. CUSHMAN, 1949, U. S. Geol. Surv., Prof. Paper 221-A, p. 7, pl. 3, fig. 18.

Diagnosis: Test small, strongly compressed, sides nearly flat, periphery rounded, adult test nearly as broad as long; chambers distinct, about 10 in the adult volution, increasing rapidly in length and gradually in height as added, with prominent lobate ventral expansions of the adult chambers into the umbilicus; sutures distinct, only slightly depressed, strongly curved; wall calcareous, finely perforate; surface smooth; aperture a low, elongate slit, interiomarginal on the ventral side.

Figured specimen: USNM 639558, length 0.30 mm, maximum breadth 0.225 mm, collected 8 feet below the top. Compared with the holotype and paratypes in USNM: agrees.

Discussion: This form is restricted to the Navarro strata. It is known only from the Arkadelphia marl and the Prairie Bluff chalk of Alabama.

Genus PULLENIA Parker and Jones, 1862

Pullenia PARKER and JONES, *in* CARPENTER, 1862, Introd. Foram., Ray Soc., London, p. 184.

Type species: Nonionina bulloides d'Orbigny, 1846, [? = *Nonionina sphaeroides* d'Orbigny, 1826 (indeterminate)]. Monotypic. *Gender:* feminine.

PULLENIA AMERICANA Cushman

Pl. VI, figs. 16, 17

Pullenia quinqueloba (Reuss). CUSHMAN and CHURCH (not *Nonionina quinqueloba* Reuss), 1929, California Acad. Sci., Proc., ser. 4, vol. 18, p. 517, pl. 41, figs. 10, 11.
Pullenia americana CUSHMAN, 1936, Cushman Lab. Foram. Res., Contr., vol. 12, pt. 4, p. 76, pl. 13, figs. 4, 5. (synonymy).
Pullenia americana Cushman. CUSHMAN, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 146, pl. 60, figs. 13, 14. (synonymy).
Pullenia americana Cushman. FRIZZELL, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 126, pl. 19, figs. 21a, b.

Diagnosis: Test planispiral, completely involute, laterally compressed, slightly umbilicate, periphery rounded; chambers distinct, somewhat inflated, 5 to 6 in the adult volution, increasing gradually in size as added; sutures distinct, somewhat depressed, slightly curved; wall calcareous, finely perforate; surface smooth; aperture elongate, arched, interiomarginal and equatorial.

Figured specimen: USNM 639559, height 0.64 mm, breadth 0.54 mm, thickness 0.34 mm, collected 8 feet below the top. The Arkadelphia specimen is much larger than the holotype of the species.

Discussion: This species is reported from numerous localities in the Taylor and Navarro of Texas, Arkansas, Mississippi, and Tennessee.

PULLENIA MINUTA Cushman

Pullenia minuta CUSHMAN, 1936, Cushman Lab. Foram. Res., Contr., vol. 12, pt. 4, p. 77, pl. 13, figs. 7a, b.
Pullenia minuta Cushman. CUSHMAN, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 147, pl. 60, fig. 12. (synonymy).
Pullenia minuta Cushman. CUSHMAN, 1949, U. S. Geol. Surv., Prof. Paper 221-A, p. 9, pl. 4, fig. 19.
Pullenia minuta Cushman. FRIZZELL, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 126, pl. 19, figs. 20a, b.

Discussion: This species, reported by Cushman (1949) from the Arkadelphia, was not identified from the samples studied by the writer. The holotype and paratypes in the USNM were examined.

Family Alabaminidae Hofker, 1951

Genus Pseudoparrella Cushman and ten Dam, 1948

Pulvinulinella Cushman (not *Pulvinulinella* Eimer and Fickert, 1899), 1926, Cushman Lab. Foram. Res., Contr., vol. 2, pt. 3, p. 62.
Pseudoparrella Cushman and ten Dam, 1948, Cushman Lab. Foram. Res., Contr., vol. 24, pt. 3, p. 49.

Type species: Pulvinulinella subperuviana Cushman, 1926. Original designation. *Gender:* feminine.

Pseudoparrella glabrata (Cushman)

Pl. VI, figs. 13, 14

Pulvinulinella glabrata Cushman, 1938, Cushman Lab. Foram. Res., Contr., vol. 14, pt. 3, p. 66, pl. 11, figs. 4a-c.
Pulvinulinella glabrata Cushman. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 144, pl. 59, figs. 10a-c. (synonymy).
Pseudoparrella glabrata (Cushman). Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 126, pl. 19, figs. 16a-c.

Diagnosis: Test small, trochospiral, biconvex, ventral side umbilicate, periphery subacute; chambers distinct, 5 or 6 in the adult volution, uniform, increasing gradually in size as added, not inflated; sutures distinct, on the dorsal side limbate, strongly oblique, slightly curved, on the ventral side subradiate, slightly depressed; wall calcareous, perforate; surface smooth, appearing polished; aperture elongate, elliptical, extending into the apertural face, subparallel to the plane of coiling, just ventral to the periphery.

Figured specimen: USNM 639560, maximum diameter 0.275 mm, collected 8 feet below the top. Compared with the holotype in USNM: agrees, though larger than the holotype.

Discussion: This species is common in the Navarro and occurs less commonly in the Taylor marl.

Pseudoparrella navarroana (Cushman)

Pl. VI, figs. 11, 12

Pulvinulinella navarroana Cushman, 1938, Cushman Lab. Foram. Res., Contr., vol. 14, pt. 3, p. 66, pl. 11, figs. 5a-c.
Pulvinulinella navarroana Cushman. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 144, pl. 60, figs. 1a-c.
Pseudoparrella navarroana (Cushman). Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 126, pl. 19, figs. 9a-c.

Diagnosis: Test trochospiral, biconvex, periphery acute with a distinct keel; chambers distinct, about 10 in the adult volution, uniform, increasing gradually in size as added, not inflated; sutures distinct, limbate, on the dorsal side strongly oblique, on the ventral side radial, somewhat sigmoid, fusing into a clear umbo at the center; wall calcareous, distinctly perforate; surface slightly granular; aperture narrow, an elongate slit, immediately below and parallel to the periphery.

Figured specimen: USNM 639561, maximum diameter 0.35 mm, collected 8 feet below the top. Compared with the holotype and paratypes in USNM: agrees perfectly.

Discussion: This species is reported only from Navarro strata. It is distinguished by the distinctly limbate sutures.

Family Cibicididae Cushman, 1927

Subfamily Cibicidinae Cushman, 1927

Genus Cibicides Montfort, 1808

Cibicides Montfort, 1808, Conch. Syst., vol. 1, p. 123.

Type species: Cibicides refulgens Montfort, 1808. Original designation. *Gender:* masculine.

Cibicides harperi (Sandidge)

Pl. VI, figs. 27, 28

[?] *Cibicides ripleyensis* Sandidge (not *Truncatulina ripleyensis* W. Berry), 1932, Amer. Midland Nat., vol. 13, no. 4, p. 199, pl. 19, figs. 17-19.
Anomalina harperi Sandidge, 1932, Amer. Midland Nat., vol. 13, no. 5, p. 316, pl. 29, figs. 5, 6 (*not* figs. 1, 2).
Cibicides harperi (Sandidge). Cushman, 1940, Cushman Lab. Foram. Res., Contr., vol. 16, pt. 2, p. 38, pl. 7, figs. 3-5.
Cibicides harperi (Sandidge) Cushman. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 159, pl. 65, figs. 5-7.
Cibicides harperi (Sandidge) Cushman. Cushman, 1949, U. S. Geol. Surv., Prof. Paper 221-A, p. 10, pl. 4, figs. 33, 34.
Cibicides harperi (Sandidge). Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 133, pl. 21, figs. 22a, b.

Diagnosis: Test trochospiral, subequally biconvex, ventral side somewhat conical, dorsal side umbilically flattened; periphery subacute, smooth in earlier portion, later lobulate; chambers numerous, about 9 in the last-formed volution, increasing gradually in size as added, the early chambers concealed on the dorsal side by a spiral of clear shell material in the umbilicus, ventral side involute with a small umbo; sutures distinct, limbate, gently curved dorsally; wall calcareous, coarsely perforate; aperture arched, basal, pe-

ripheral, extending a short distance onto the dorsal side.

Figured specimen: USNM 639562, maximum diameter 0.325 mm, collected 10 feet below the top. Compared with plesiotypes from the Arkadelphia in USNM: compares favorably.

Discussion: This species is reported from the Navarro of Texas, Arkansas, and Alabama.

Cibicides beaumontianus (d'Orbigny)

Pl. VI, figs. 29, 30

Truncatulina beaumontiana d'Orbigny, 1840, Soc. Géol. France, Mém., sér. 1, vol. 4, p. 35, pl. 3, figs. 17-19.
Cibicides involuta (Reuss). Cushman (not *Rotalina involuta* Reuss), 1931, Jour. Paleontology, vol. 5, no. 4, p. 315, pl. 36, figs. 10a-c.
Cibicides beaumontiana (d'Orbigny). Brotzen, 1936, Sveriges Geol. Undersökning, Afh., ser. C, no. 396, vol. 30, pt. 3, p. 188.
Cibicides beaumontianus (d'Orbigny). Cushman, 1940, Cushman Lab. Foram. Res., Contr., vol. 16, pt. 2, p. 39, pl. 7, figs. 9a-c.
Cibicides beaumontianus (D'Orbigny). Brotzen. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 160, pl. 65, figs. 12a-c. (synonymy).
Cibicides beaumontianus (d'Orbigny) Brotzen. Cushman, 1949, U. S. Geol. Surv., Prof. Paper 221-A, p. 10, pl. 4, figs. 37, 38.
Cibicides beaumontianus (d'Orbigny). Frizzell, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Invest. 22, p. 132, pl. 21, figs. 19a-c.

Diagnosis: Test trochospiral, planoconvex, dorsal surface flattened or slightly concave, evolute, ventral side strongly convex, involute, periphery acute, slightly lobulate; chambers distinct, about 7 or 8 in the adult volution, slightly inflated ventrally, increasing rapidly in size as added; sutures distinct, earlier ones slightly limbate, strongly curved, later ones slightly depressed on the ventral side; wall calcareous, perforate; surface smooth, or somewhat thickened at the sutures in the dorsal umbilicus; aperture a low opening at the periphery extending onto the dorsal side at the base of the last-formed chamber.

Figured specimen: USNM 639563, maximum diameter 0.54 mm, collected 8 feet below the top. Compared with plesiotypes in USNM: atypical but within the range of the plesiotypes though most are larger and more strongly inflated.

Discussion: This species is fairly common in the Taylor and Navarro strata of Texas, Arkansas, Alabama, and Mississippi.

Cibicides subcarinatus Cushman and Deaderick

Cibicides subcarinatus Cushman and Deaderick, 1944, Jour. Paleontology, vol. 18, no. 4, p. 341.
Cibicides subcarinatus Cushman and Deaderick. Cushman, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 159, pl. 65, figs. 8-11. (synonymy).
Cibicides subcarinatus Cushman and Deaderick. Cushman, 1949, U. S. Geol. Surv., Prof. Paper 221-A, p. 10, pl. 4, figs. 35, 36.

Discussion: This species, reported by Cushman (1949) from the Arkadelphia, was not identified from the samples studied by the writer.

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Numerous papers used only in checking and compiling synonymies are omitted from the list of references.

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PLATES I-VI

ALL FIGURES ARE X48 UNLESS OTHERWISE NOTED

Plate I

		Page
1.	*Reophax difflugiformis arenulata* Skinner	4
2.	*Reophax texana* Cushman and Waters	5
3.	*Ammodiscus cretaceus* (Reuss)	3
4.	*Haplophragmoides calculus* Cushman and Waters	5
5.	*Haplophragmoides glaber* Cushman and Waters	5
6.	*Haplophragmoides rugosus* Cushman and Waters	6
7.	*Haplophragmoides excavatus* Cushman and Waters	6
8.	*Ammobaculites arenatus* Cushman	6
9.	*Ammobaculites coprolithiformis* (Schwager)	6
10.	*Ammobaculites texanus* Cushman	7
11.	*Spiroplectammina semicomplanata* (Carsey)	8
12.	*Spiroplectammina semicomplanata juncea* Cushman	8
13.	*Gaudryina (Gaudryina) deadericki* Cushman	9
14.	*Gaudryina (Gaudryina) navarroana* Cushman	9
15.	*Gaudryinella pseudoserrata* Cushman	10
16.	*Gaudryinella pseudoserrata extensa* Cushman	10
17.	*Pseudoclavulina arenata* (Cushman)	10
18.	*Gaudryina (Gaudryina) navarroana* Cushman	9
19.	*Clavulinoides insignis* (Plummer) microspheric individual	11
20.	*Clavulinoides insignis* (Plummer) megalospheric individual	11
21.	*Marssonella oxycona* (Reuss)	11
22.	*Dorothia bulletta* (Carsey)	12
23.	*Dorothia conula* (Reuss)	12

PLATE I

Plate II

Page

1. *?Goesella rugulosa* Cushman 13
   lateral view of form showing strong tendency to become uniserial
2. *?Plectina watersi* Cushman 12
   lateral view of form with two proloculi
3. *?Goesella rugulosa* Cushman 13
4. *Goesella rugulosa* Cushman 13
5. *Goesella rugulosa* Cushman 13
6. *Quinqueloculina* sp. 13
7. *Trochammina texana* Cushman and Waters 8
   dorsal view
8. *Trochammina texana* Cushman and Waters 8
   ventral view
9. *Trochammina gyroides* Cushman and Waters 9
   dorsal view
10. *Trochammina gyroides* Cushman and Waters 9
    ventral view
11. *Lenticulina (Robulus) navarroensis* (Plummer) 15
12. *Lenticulina (Robulus) navarroensis extruatus* (Cushman) 15
13. *Lenticulina (Robulus) pondi* (Cushman) 16
14. *Lenticulina (Robulus) spissocostatus* (Cushman) 16
15. *Lenticulina (Robulus) muensteri* (Roemer) 16
16. *Lenticulina (Lenticulina) rotulata* (Lamarck) 14

PLATE II

Plate III

Page

1. *Darbyella* sp. 17
2. *Darbyella* sp. 17
3. *Planularia dissona* (Plummer) 17
4. *Planularia deadericki* Cushman 17
5. *Marginulina* sp. 18
6. *Marginulina plummerae* Cushman 18
7. *Marginulina curvatura* Cushman 19
8. *Marginulina siliqua* Cushman 19
9. *Dentalina legumen* (Reuss) 19
10. *Dentalina gracilis* (d'Orbigny) 19
11. *Dentalina gracilis* (d'Orbigny) 19
12. *Dentalina lorneiana* d'Orbigny 20
13. *Dentalina lorneiana* d'Orbigny 20
14. *Dentalina aculeata* (d'Orbigny) 20
15. *Dentalina catenula* Reuss 20
16. *Dentalina catenula* Reuss, X24 20
17. *Dentalina basiplanata* Cushman 21
18. *Dentalina crinita* Plummer, X24 21
19. *Dentalina delicatula* Cushman 21
20. *Nodosaria vertebralis* (Batsch), X24 22
21. *Nodosaria affinis* Reuss, X24 22
    microspheric individual
22. *Nodosaria affinis* Reuss, X24 22
    megalospheric individual
23. *Nodosaria obscura* Reuss 22
24. *Chrysalogonium texanum* Cushman, X24 23

PLATE III

Plate IV

Page

1. *Rectoglandulina appressa* Loeblich and Tappan 24
2. *Pseudonodosaria larva* (Carsey) 23
3. *Rectoglandulina lagenoides* (Olszewski) 24
4. *Rectoglandulina pygmaea* (Reuss) 24
5. *Saracenaria triangularis* (d'Orbigny) 25
6. *Saracenaria saratogana* Howe and Wallace 25
7. *Citharina barcoensis* (Cushman and Hedberg) 26
8. *Citharina simondsi* (Carsey) 26
9. *Vaginulina cretacea* Plummer, X24 25
10. *Vaginulina cretacea* Plummer, X24 25
11. *Citharina webbervillensis* (Carsey), X24 27
12. *Neoflabellina rugosa* (d'Orbigny) 27
13. *Neoflabellina reticulata* (Reuss) 28
14. *Neoflabellina reticulata* (Reuss) 28
15. *Frondicularia inversa* Reuss 28
16. *Pseudofrondicularia arkadelphiana* (Cushman) 28
17. *Lagena hispida* Reuss 13
18. *Lagena hispida* Reuss 13
19. *Lagena sulcata semiinterrupta* Berry 14
20. *Guttulina adhaerens* (Olszewski) 29
21. *Globulina lacrima lacrima* Reuss 29
22. *Globulina lacrima subsphaerica* (Berthelin) 30
23. *Globulina lacrima horrida* Reuss 30
24. *Globulina prisca* Reuss 30
25. *Pyrulina cylindroides* (Roemer) 31

PLATE IV

Plate V

Page

1. *Pseudopolymorphina cuyleri* Plummer 31
2. *Ramulina arkadelphiana* Cushman 32
3. *Ramulina globotubulosa* Cushman 32
4. *Vitriwebbina biosculata* Frizzell 31
5. *Nonionella robusta* Plummer 48
6. *Nonionella robusta* Plummer 48
7. *Nonionella ansata* Cushman 49
8. *Bolivinopsis rosula* (Ehrenberg) 7
9. *Heterohelix plummerae* (Loetterle) 39
10. *Heterohelix striata* (Ehrenberg) 39
11. *Heterohelix globulosa* (Ehrenberg) 39
12. *Pseudoguembelina costulata* (Cushman) 40
13. *Guembelitria cretacea* Cushman 38
14. *Racemiguembelina fructicosa* (Egger) 41
15. *Planoglobulina glabrata* (Cushman) 42
16. *Planoglobulina austinana* (Cushman) 42
17. *Pseudotextularia elegans* (Rzehak) 40
18. *Planoglobulina carseyae* (Plummer) 42
19. *Pseudouvigerina seligi* (Cushman) 35
20. *Siphogenerinoides plummeri* (Cushman) 35
21. *Buliminella cushmani* Sandidge 32
22. *Bulimina aspera* Cushman and Parker 36
23. *Bulimina arkadelphiana* Cushman and Parker 36
24. *Bulimina arkadelphiana* Cushman and Parker 36
    apertural view
25. *Fursenkoina navarroana* (Cushman) 46
26. *Loxostomum cushmani* Wickenden 34
27. *Loxostomum gemma* (Cushman) 34
28. *Loxostomum gemma* (Cushman) 34
29. *Loxostomum plaitum* (Carsey) 34
30. *Stilostomella stephensoni* (Cushman) 47
31. *Stilostomella stephensoni speciosa* (Cushman) 47
32. *Stilostomella alexanderi impensia* (Cushman) 48

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32

PLATE V

Plate VI

Page

1. *Gyroidina depressa* (Alth) 37
   dorsal view
2. *Gyroidina depressa* (Alth) 37
   ventral view
3. *Gyroidina depressa* (Alth) 37
   dorsal view
4. *Gyroidina depressa* (Alth) 37
   ventral view
5. *Gyroidina arkadelphiana* Cushman 37
   dorsal view
6. *Gyroidina arkadelphiana* Cushman 37
   ventral view
7. *Stensioina americana* Cushman and Dorsey 37
   dorsal view
8. *Stensioina americana* Cushman and Dorsey 37
   ventral view
9. *Siphonina prima* Plummer 38
   dorsal view
10. *Siphonina prima* Plummer 38
    ventral view
11. *Pseudoparrella navarroana* (Cushman) 50
    dorsal view
12. *Pseudoparrella navarroana* (Cushman) 50
    ventral view
13. *Pseudoparrella glabrata* (Cushman) 50
    dorsal view
14. *Pseudoparrella glabrata* (Cushman) 50
    ventral view
15. *Allomorphina navarroana* Cushman 48
    ventral view.
16. *Pullenia americana* Cushman 49
    lateral view
17. *Pullenia americana* Cushman 49
    apertural view
18. *Rugoglobigerina rugosa* (Plummer) 45

19. *Globotruncana cretacea* Cushman 43
    dorsal view
20. *Globotruncana cretacea* Cushman 43
    ventral view
21. *Globotruncana gansseri* Bolli 44
    dorsal view
22. *Globotruncana gansseri* Bolli 44
    ventral view
23. *Anomalina pseudopapillosa* Carsey 45
    dorsal view

1
2
3
4
5
6
7
9
10
11
8
12
13
14
15
16
17
18
19
21
20
22
23
24
25
27
29
26
28
30

PLATE VI

Page

24. *Anomalinoides pinguis* (Jennings) ---- 46
dorsal view
25. *Planulina correcta* (Carsey) ---- 46
dorsal view
26. *Planulina correcta* (Carsey) ---- 46
ventral view
27. *Cibicides harperi* (Sandidge) ---- 50
dorsal view
28. *Cibicides harperi* (Sandidge) ---- 50
ventral view
29. *Cibicides beaumontianus* (d'Orbigny) ---- 51
dorsal view
30. *Cibicides beaumontianus* (d'Orbigny) ---- 51
ventral view

INDEX TO SYNONYMIES

Taxonomic combinations which are accepted as valid are listed in ordinary type; those which are obsolete are listed in italics.

acervulinoides, Guembelina ... 41
acervulinoides, Planoglobulina ... 41
acervulinoides, Pseudotextularia ... 41
aculeata, Dentalina ... 20
aculeata, Nodosaria (Dentalina) ... 20
adhaerens, Guttulina ... 29
adhaerens, Polymorphina ... 29
affinis, Nodosaria ... 22
agglutinans, Ammobaculites ... 6
agglutinans biformis, Textularia ... 7
agglutinans, Spirolina ... 6
alexanderi, Ellipsonodosaria ... 47
alexanderi impensia, Stilostomella ... 48
alexanderi impensia, Ellipsonodosaria ... 48
alexanderi, Stilostomella ... 47
Allomorphina ... 48
  navarroana ... 48
  trigona ... 48
alternata, Dentalina ... 22
americana, Eouvigerina ... 35
americana, Heterohelix ... 39
americana, Pullenia ... 49
americana, Spiroplecta ... 39
americana, Stensioina ... 37
Ammobaculites ... 5, 6
  agglutinans ... 6
  arenatus ... 6
  coprolithiformis ... 6
  texanus ... 7
Ammodiscus ... 3
  cretaceus ... 3
  infimis ... 3
anceps, Spiroplectammina ... 8
angusta, Quinqueloculina antiqua ... 13
annulata, Dentalina ... 21
Anomalina ... 45
  grosserugosa ... 46
  harperi ... 50
  involuta ... 45
  navarroensis ... 45
  nelsoni ... 45
  pinguis ... 46
  pseudopapillosa ... 45
  punctulata ... 45
Anomalinoides ... 45
  pinguis ... 46
  plummerae ... 46
ansata, Nonionella ... 49
antiqua angusta, Quinqueloculina ... 13
appressa, Rectoglandulina ... 24
arca, Globotruncana ... 43, 44
arca, Pulvinulina ... 43
arenata, Clavulina ... 10
arenata, Pseudoclavulina ... 10
arenatus, Ammobaculites ... 6
arenulata, Reophax difflugiformis ... 4
ariminensis, Planulina ... 46
arkadelphiana, Bulimina ... 36
arkadelphiana, Frondicularia ... 28
arkadelphiana, Gyroidina ... 37
arkadelphiana, Pseudofrondicularia ... 28
arkadelphiana, Ramulina ... 32
aspera, Bulimina ... 36
Astacolus ... 14, 17
  dissonus ... 17
atlantica, Proteonina ... 4
atlantica, Reophax ... 4
auris, Peneroplis ... 17
auris, Planularia ... 17
austinana, Planoglobulina ... 42
austinana, Ventilabrella ... 42
austinensis, Nodosaria vertebralis ... 22
barcoensis, Citharina ... 26
barcoensis, Vaginulina ... 26
basiplanata, Dentalina ... 21
baudouiniana, Frondicularia ... 27
beaumontiana, Truncatulina ... 51
beaumontianus, Cibicides ... 51
beccarii ripleyensis, Rotalia ... 37
biformis, Spiroplecta ... 7
biformis, Textularia agglutinans ... 7
biosculata, Vitriwebbina ... 31
bohemica, Pseudotextularia ... 40
Bolivina ... 33
  decurrens ... 33
  gemma ... 34
  incrassata ... 33
  incrassata lata ... 33
  plaita ... 34
  plicata ... 33
  primatumida ... 33
Bolivinita ... 33
  costifera ... 33
  quadrilatera ... 33
Bolivinopsis ... 7
  capitata ... 7
  rosula ... 7
brevispinosa, Siphogenerinoides ... 35
Bulimina ... 36
  arkadelphiana ... 36
  aspera ... 36
  elegantissima ... 32
  elongata ... 36
  kickapooensis ... 36
  marginata ... 36
  obtusa ... 36
  prolixa ... 36
  pupoides ... 36
  puschi ... 36
  quadrata ... 36
  subornata ... 36
Buliminella ... 32
  carseyae ... 32
  cushmani ... 32
  elegantissima ... 32
bulletta, Dorothia ... 12
bulletta, Gaudryina ... 12
bulloides, Nonionina ... 49
bulloides, Pullenia ... 49
Bullopora laevis ... 31
calculus, Haplophragmoides ... 5
canaliculata, Globigerina ... 43
canaliculata, Globotruncana ... 43
canaliculata, Rosalina ... 43
canariensis, Haplophragmoides ... 5
canariensis, Nonionina ... 5
capitata, Bolivinopsis ... 7
carinata, Frondicularia ... 28
carinata expansa, Textularia ... 8
carseyae, Buliminella ... 32
carseyae, Guembelina ... 42
carseyae, Planoglobulina ... 42
carseyae, Ventilabrella ... 42
catenula, Dentalina ... 20
chapmani, Vitriwebbina ... 32
Chrysalogonium ... 23
  granti ... 23
  polystoma ... 23
  texanum ... 23
Cibicides ... 50
  beaumontianus ... 51
  excolata ... 37
  harperi ... 50
  involuta ... 51
  nelsoni ... 45
  refulgens ... 50
  ripleyensis ... 50
  subcarinatus ... 51
Citharina ... 26
  barcoensis ... 26
  multicostata ... 26
  navarroana ... 27
  simondsi ... 26
  strigillata ... 26
  webbervillensis ... 27
clavata, Clavulina ... 10
clavatum, Loxostomum ... 34
Clavulina ... 10
  arenata ... 10
  clavata ... 10
  compressus ... 11
  insignis ... 11
  rotundata ... 13
  trilatera ... 11
Clavulinoides ... 10
  compressus ... 11

insignis ... 11
trilaterus ... 11
trilaterus concavus ... 11
communis, Polymorphina (Guttulina) ... 29
complanata, Frondicularia ... 28
complanata, Renulina ... 28
compressa, Clavulina ... 11
compressus, Clavulinoides ... 11
concavus, Clavulinoides trilaterus ... 11
consobrina Nodosaria ... 21
conula, Dorothia ... 12
conulus, Textularia ... 12
coprolithiforme, Haplophragmium ... 6
coprolithiformis, Ammobaculites ... 6
Cornuspira ... 3
cretacea ... 3
involvens ... 3
correcta, Discorbis ... 46
correcta, Planulina ... 46
costifera, Bolvinita ... 33
costulata, Guembelina ... 40
costulata, Pseudoguembelina ... 40
cretacea, Cornuspira ... 3
cretacea, Globigerina ... 45
cretacea, Globotruncana ... 43
cretacea, Guembelitria ... 38
cretacea, Marginulina ... 18
cretacea, Operculina ... 3
cretacea, Rectoguembelina ... 40
cretacea, Rotalia ... 37
cretacea, Tubitextularia ... 40
cretacea, Vaginulina ... 25
cretacea, Valvulineria ... 37
cretaceus, Ammodiscus ... 3
crinita, Dentalina ... 21
cristata, Uvigerina ... 35
Cristellaria ... 14
cultrata ... 15
lineara ... 18
midwayensis ... 15
muensteri ... 16
navarroensis ... 15
pseudomamilligerus ... 16
reniformis ... 17
rotulata ... 14
triangularis ... 25
cultrata, Cristellaria ... 15
cultratus, Lenticulina ... 15
cultratus, Robulus ... 15
Cuneolina elegans ... 40, 41
curvatura, Marginulina ... 18, 19
cushmani, Buliminella ... 32
cushmani, Loxostomum ... 34
cuvieri, Dentalina ... 19
cuvieri, Nodosaria (Dentaline) ... 19
cuyleri, Pseudopolymorphina ... 31
cylindroides, Polymorphina ... 31
cylindroides, Pyrulina ... 31
danvillensis, Darbyella ... 17
Darbyella ... 17
danvillensis ... 17
deadericki, Gaudryina ... 9
deadericki, Planularia ... 17
decurrens, Bolivina ... 33
decurrens, Grammostomum ... 33
delicatula, Dentalina ... 21
delrioensis, Gaudryinella ... 10
Dentalina ... 19
aculeata ... 20
alternata ... 22
annulata ... 21
basiplanata ... 21
catenula ... 20
consobrina ... 21
crinita ... 21
cuvieri ... 19
delicatula ... 21
gracilis ... 19, 21
granti ... 23
legumen ... 19
lorneiana ... 20
megalopolitana ... 21
nana ... 19
obliqua ... 21
reussi ... 21
soluta ... 20
vertebralis ... 22
depressa, Gyroidina ... 37
depressa, Rotalina ... 37
difflugiformis, Reophax ... 4
difflugiformis arenulata, Reophax ... 4
difflugiformis, Proteonina ... 4
difflugiformis lagenarium, Proteonina ... 4
Discorbis correcta ... 46
discreta, Glandulina ... 23
dissona, Planularia ... 17
dissonus, Astacolus ... 17
Dorothia ... 12
bulletta ... 12
conula ... 12
eggeri glabrata, Ventilabrella ... 42
eggeri, Ventilabrella ... 42
elegans, Cuneolina ... 40, 41
elegans, Pseudotextularia ... 40, 42
elegantissima, Bulimina ... 32
elegantissima, Buliminella ... 32
Ellipsonodosaria alexanderi impensia ... 48
Ellipsonodosaria granti ... 23
Ellipsonodosaria stephensoni ... 47
Ellipsonodosaria stephensoni speciosa ... 47
elongata, Bulimina ... 36
ensis, Hemicristellaria ... 18
Eouvigerina americana ... 35
excavatus, Haplophragmoides ... 6
excolata, Cibicides ... 37
excolata, Guembelina ... 40
excolata, Pseudoguembelina ... 40
exsculpta, Rotalia ... 37
exsculpta, Stensioina ... 37
extensa, Gaudryinella pseudoserrata ... 10
extruatus, Lenticulina (Robulus) navarroensis ... 15
farcimen, Nodosaria ... 20
favosa, Flabellina ... 28
filiformis, Nodosaria ... 23
fimbriata, Siphonina ... 38
Flabellina favosa ... 28
Flabellina interpunctata ... 27
Flabellina reticulata ... 28
Flabellina rugosa ... 27
Frondicularia ... 28
arkadelphiana ... 28
baudouiniana ... 27
carinata ... 28
complanata ... 28
interpunctata ... 28
inversa ... 28
lanceola ... 29
reticulata ... 28
fructicosa, Guembelina ... 41
fructicosa, Racemiguembelina ... 41
Fursenkoina ... 46
navarroana ... 46
squammosa ... 46
fusiformis, Polymorphina ... 31
fusiformis, Proteonina ... 4
gansseri, Globotruncana ... 44
Gaudryina ... 9
bulletta ... 12
deadericki ... 9
navarroana ... 9, 11
oxycona ... 11
rugosa ... 9
ruthenica ... 12
stephensoni ... 9, 10
Gaudryinella ... 10
delrioensis ... 10
pseudoserrata ... 10
pseudoserrata extensa ... 10
gemma, Bolivina ... 34
gemma, Loxostomum ... 34
gibba, Globulina ... 29
gibba, Polymorphina ... 30
gibba, Polymorphina (Globuline) ... 29
glaber, Haplophragmoides ... 5, 6
glabrata, Planoglobulina ... 42
glabrata, Pseudoparrella ... 50
glabrata, Pulvinulinella ... 50
glabrata, Ventilabrella eggeri ... 42
Glandulina discreta ... 23
Glandulina lagenoides ... 24
Glandulina pygmaea ... 24
globifera, Textularia ... 39
Globigerina canaliculata ... 43
Globigerina cretacea ... 45
Globigerina rosetta ... 43
Globigerina rugosa ... 45
Globorotalia ... 44
membranacea ... 44
menardii tumida ... 44
Globotruncana ... 43
arca ... 43, 44
canaliculata ... 43

cretacea . . . 43
gansseri . . . 44
globotubulosa, Ramulina . . . 32
globulifera, Ramulina . . . 20
Globulina . . . 29
gibba . . . 29
inaequalis . . . 30
lacrima lacrima . . . 29
lacrima horrida . . . 30
lacrima subsphaerica . . . 30
prisca . . . 30
globulosa, Guembelina . . . 39
globulosa, Heterohelix . . . 39, 42
globulosa, Textularia . . . 39, 42
Goesella . . . 13
rotundata . . . 13
rugulosa . . . 13
gracilis cretacea, Vaginulina . . . 25
gracilis, Dentalina . . . 19, 21
Grammostomum decurrens . . . 33
granti, Chrysalogonium . . . 23
granti, Dentalina . . . 23
granti, Ellipsonodosaria . . . 23
granti, Nodosaria . . . 23
grosserugosa, Anomalina . . . 45
Guembelina . . . 39
acervulinoides . . . 41
carseyae . . . 42
costulata . . . 40
excolata . . . 40
fructicosa . . . 41
globulosa . . . 39, 42
plummerae . . . 39
pupa . . . 39
striata . . . 39
Guembelitria . . . 38
cretacea . . . 38
gutta, Polymorphina . . . 31
gutta, Polymorphina (Pyruline) . . . 31
Guttulina . . . 29
adhaerens . . . 29
communis . . . 29
problema . . . 29
gyroides, Trochammina . . . 9
Gyroidina . . . 37
arkadelphiana . . . 37
depressa . . . 37
orbicularis . . . 37
orbiculus . . . 37
hanzawai, Pseudopolymorphina . . . 31
Haplophragmium . . . 4
coprolithiforme . . . 6
lagenarium . . . 4
Haplophragmoides . . . 5
calculus . . . 5
canariensis . . . 5
excavatus . . . 6
glaber . . . 5, 6
rugosus . . . 6
harperi, Anomalina . . . 50
harperi, Cibicides . . . 50
Hemicristellaria ensis . . . 18
Hemicristellaria silicula . . . 18
Heterohelix . . . 39
americana . . . 39
globulosa . . . 39, 42
plummerae . . . 39
striata . . . 39
hispida, Lagena . . . 13
horrida, Globulina . . . 30
horrida, Globulina lacrima . . . 30
humilis, Nodosaria . . . 23
impensia, Ellipsonodosaria alexanderi . . . 48
impensia, Stilostomella alexanderi . . . 48
inaequalis, Globulina . . . 30
incidenta, Lagena . . . 20
incrassata, Bolivina . . . 33
incrassata lata, Bolivina . . . 33
infimis, Ammodiscus . . . 3
inflatus, Nautilus . . . 8
inflatus, Trochammina . . . 8
insignis, Clavulina . . . 11
insignis, Clavulinoides . . . 11
interpunctata, Flabellina . . . 27
interpunctata, Frondicularia . . . 28
inversa, Frondicularia . . . 28
involuta, Anomalina . . . 45
involuta, Cibicides . . . 51
involuta, Rotalina . . . 45, 51
involvens, Cornuspira . . . 3
italica, Saracenaria . . . 25
jonesi, Lenticulina . . . 15
juncea, Spiroplectammina semicomplanata . . . 8
kickapooensis, Bulimina . . . 36
lacrima, Globulina . . . 29
lacrima horrida, Globulina . . . 30
lacrima subsphaerica, Globulina . . . 30
lacrima, Polymorphina (Globulina) . . . 29
laevigata, Nodosaria . . . 24
laevis, Bullopora . . . 31
laevis, Ramulina . . . 32
Lagena . . . 13
hispida . . . 13
incidenta . . . 20
sulcata . . . 13, 14
sulcata semiinterrupta . . . 14
lagenarium, Haplophragmium . . . 4
lagenarium, Proteonina difflugiformis . . . 4
lagenoides, Glandulina . . . 24
lagenoides, Pseudoglandulina . . . 24
lagenoides, Rectoglandulina . . . 24
lanceola, Frondicularia . . . 29
lanceola, Pseudofrondicularia . . . 29
larva, Nodosaria . . . 23
larva, Pseudonodosaria . . . 23
lata, Bolivina incrassata . . . 33
legumen, Dentalina . . . 19
legumen, Nautilus . . . 25
legumen, Nodosaria (Dentalina) . . . 19
legumen, Vaginulina . . . 25
Lenticulina . . . 14
cultratus . . . 15
jonesi . . . 15
muensteri . . . 16
navarroensis . . . 15
navarroensis extruatus . . . 15
pondi . . . 16
rotulata . . . 14
spissocostatus . . . 16
Lenticulites rotulata . . . 14
lineara, Cristellaria . . . 18
lorneiana, Dentalina . . . 20
lorneiana, Nodosaria . . . 20
Loxostomum . . . 33
clavatum . . . 34
cushmani . . . 34
gemma . . . 34
plaitum . . . 34
subrostratum . . . 33
manifesta, Nodosaria (Glandulina) . . . 23
manifesta, Pseudoglandulina . . . 23
marginata, Bulimina . . . 36
Marginulina . . . 14, 18
cretacea . . . 18
curvatura . . . 18, 19
navarroana . . . 18
plummerae . . . 18
silicula . . . 18
siliqua . . . 19
raphanus . . . 18
marla, Nodosaria . . . 22
Marssonella . . . 11
oxycona . . . 11
megalopolitana, Dentalina . . . 21
membranacea, Globorotalia . . . 44
menardii tumida, Pulvinulina . . . 44
mendezensis, Pseudopolymorphina . . . 31
midwayensis, Cristellaria . . . 15
minuta, Pullenia . . . 49
miocenica, Nonionella . . . 48
muensteri, Cristellaria . . . 16
muensteri, Lenticulina (Robulus) . . . 16
muensteri, Robulina . . . 16
multicostata, Citharina . . . 26
multicostata, Vaginulina . . . 26
nana, Dentalina . . . 19
Nautilus . . . 8
inflatus . . . 8
legumen . . . 25
(Orthoceras) vertebralis . . . 22
radicula . . . 22
raphanus . . . 18
navarroana, Allomorphina . . . 48
navarroana, Citharina . . . 27
navarroana, Fursenkoina . . . 46
navarroana, Gaudryina . . . 9, 11
navarroana, Marginulina . . . 18
navarroana, Pseudoparrella . . . 50
navarroana, Pulvinulinella . . . 50
navarroana, Vaginulina . . . 27
navarroana, Virgulina . . . 46
navarroensis, Anomalina . . . 45
navarroensis, Cristellaria . . . 15
navarroensis, Lenticulina (Robulus) . . . 15

nelsoni, Anomalina ... 45
nelsoni, Cibicides ... 45
nelsoni, Valvulineria ... 45
Neoflabellina ... 27
reticulata ... 28
rugosa ... 27
Nodosaria ... 22
affinis ... 22
consobrina ... 21
(Dentalina) aculeata ... 20
(Dentalina) gracilis ... 19, 21
(Dentalina) legumen ... 19
(Dentaline) cuvieri ... 19
farcimen ... 20
filiformis ... 23
granti ... 23
humilis ... 23
laevigata ... 24
larva ... 23
lorneiana ... 20
manifesta ... 23
marla ... 22
nana ... 19
obliqua ... 21
obscura ... 22
polystoma ... 23
proxima ... 22
radicula ... 22, 23
vertebralis ... 22
vertebralis austinensis ... 22
zippei ... 22
Nonionella ... 48
ansata ... 49
miocenica ... 48
robusta ... 48
Nonionina bulloides ... 49
Nonionina canariensis ... 5
Nonionina quinqueloba ... 49
Nonionina scapha ... 48
Nonionina sphaeroides ... 49
obliqua, Dentalina ... 21
obliqua, Nodosaria ... 21
obscura, Nodosaria ... 22
obtusa, Bulimina ... 36
Operculina cretacea ... 3
orbicularis, Gyroidina ... 37
orbiculus, Gyroidina ... 37
oxycona, Gaudryina ... 11
oxycona, Marssonella ... 11
Palmula reticulata ... 28
Palmula rugosa ... 27
Peneroplis auris ... 17
pinguis, Anomalina ... 46
pinguis, Anomalinoides ... 46
plaita, Bolivina ... 34
plaita, Propoporus ... 34
plaitum, Loxostomum ... 34
Planoglobulina ... 41
acervulinoides ... 41
austinana ... 42
carseyae ... 42
glabrata ... 42
planotrochiformis, Planularia ... 17
Planularia ... 17
auris ... 17
deadericki ... 17
dissona ... 17
planotrochiformis ... 17
Planulina ... 46
ariminensis ... 46
correcta ... 46
Plectina ... 12
ruthenica ... 12
watersi ... 12, 13
plicata, Bolivina ... 33
plummerae, Anomalinoides ... 46
plummerae, Guembelina ... 39
plummerae, Heterohelix ... 39
plummerae, Marginulina ... 18
plummerae, Ventilabrella ... 39, 42
plummeri, Siphogenerina ... 35
plummeri, Siphogenerinoides ... 35
Polymorphina ... 29
adhaerens ... 29
cylindroides ... 31
fusiformis ... 31
gibba ... 29
(Globulina) lacrima ... 29
(Globuline) gibba ... 29
gutta ... 31
(Guttulina) communis ... 29
(Pyruline) gutta ... 31
subsphaerica ... 30
polystoma, Nodosaria ... 23
pondi, Lenticulina (Robulus) ... 16
prima, Siphonina ... 38
primatumida, Bolivina ... 33
prisca, Globulina ... 30
problema, Guttulina ... 29
prolixa, Bulimina ... 36
Propoporus plaita ... 34
Proteonina ... 4
atlantica ... 4
difflugiformis ... 4
difflugiformis lagenarium ... 4
fusiformis ... 4
proxima, Nodosaria ... 22
Pseudoclavulina ... 10
arenata ... 10
clavata ... 10
Pseudofrondicularia ... 28
arkadelphiana ... 28
carinata ... 28
lanceola ... 29
Pseudoglandulina lagenoides ... 24
Pseudoglandulina manifesta ... 23
Pseudoglandulina pygmaea ... 24
Pseudoguembelina ... 40
costulata ... 40
excolata ... 40
pseudomamilligerus, Cristellaria ... 16
Pseudonodosaria ... 23
discreta ... 23
larva ... 23
pseudopapillosa, Anomalina ... 45
Pseudoparrella ... 50
glabrata ... 50
navarroana ... 50
subperuviana ... 50
Pseudopolymorphina ... 31
cuyleri ... 31
hanzawai ... 31
mendezensis ... 31
pseudoserrata, Gaudryinella ... 10
pseudoserrata extensa, Gaudryinella ... 10
Pseudotextularia ... 40
a, d ... 42
acervulinoides ... 41
bohemica ... 40
elegans ... 40, 41, 42
varians ... 40, 41
Pseudouvigerina ... 35
cristata ... 35
seligi ... 35
Pullenia ... 49
americana ... 49
bulloides ... 49
minuta ... 49
quinqueloba ... 49
Pulvinulina ... 43
arca ... 43
menardii tumida ... 44
rosetta ... 43
Pulvinulinella ... 50
glabrata ... 50
navarroana ... 50
subperuviana ... 50
punctulata, Anomalina ... 45
pupa, Guembelina ... 39
pupoides, Bulimina ... 36
puschi, Bulimina ... 36
pygmaea, Glandulina ... 24
pygmaea, Pseudoglandulina ... 24
pygmaea, Rectoglandulina ... 24
Pyrulina ... 31
cylindroides ... 31
fusiformis ... 31
gutta ... 31
quadrata, Bulimina ... 36
quadrilatera, Bolivinita ... 33
quadrilatera, Textularia ... 33
quinqueloba, Nonionina ... 49
quinqueloba, Pullenia ... 49
Quinqueloculina ... 13
antiqua angusta ... 13
seminulum ... 13
Racemiguembelina ... 41
fructicosa ... 41
radicula, Nautilus ... 22, 23
radicula, Nodosaria ... 22, 23
Ramulina ... 20, 32
arkadelphiana ... 32

globulifera ... 20
globotubulosa ... 32
laevis ... 32
raphanus, Marginulina ... 18
raphanus, Nautilus ... 18
Rectoglandulina ... 24
appressa ... 24
lagenoides ... 24
pygmaea ... 24
Rectoguembelina cretacea ... 40
reflugens, Cibicides ... 50
reniformis, Cristellaria ... 17
Renulina complanata ... 28
Reophax ... 4
atlantica ... 4
difflugiformis ... 4
difflugiformis arenulata ... 4
scorpiurus ... 4
texana ... 5
reticulata, Flabellina ... 28
reticulata, Frondicularia ... 28
reticulata, Neoflabellina ... 28
reticulata, Palmula ... 28
reussi, Dentalina ... 21
ripleyensis, Cibicides ... 50
ripleyensis, Rotalia beccarii ... 37
ripleyensis, Truncatulina ... 50
Robulina muensteri ... 16
Robulus ... 15
cultratus ... 15
muensteri ... 16
navarroensis ... 15
navarroensis extruatus ... 15
pondi ... 16
spissocostatus ... 16
robusta, Nonionella ... 48
Rosalina canaliculata ... 43
rosetta, Globigerina ... 43
rosetta, Pulvinulina ... 43
rosula, Bolivinopsis ... 7
rosula, Spiroplecta ... 7
rosula, Spiroplectoides ... 7
Rotalia beccarii ripleyensis ... 37
Rotalia cretacea ... 37
Rotalia exsculpta ... 37
Rotalina depressa ... 37
Rotalina involuta ... 45, 51
rotulata, Cristellaria ... 14
rotulata, Lenticulina ... 14
rotulata, Lenticulites ... 14
rotundata, Clavulina ... 13
rotundata, Goesella ... 13
Rugoglobigerina ... 44
rugosa ... 45
rugosa, Flabellina ... 27
rugosa, Gaudryina ... 9
rugosa, Globigerina ... 45
rugosa, Neoflabellina ... 27
rugosa, Palmula ... 27
rugosa, Rugoglobigerina ... 45
rugosa, Stilostomella ... 47
rugosus, Haplophragmoides ... 6
rugulosa, Goesella ... 13
ruthenica, Gaudryina ... 12
ruthenica, Plectina ... 12
Saracenaria ... 14, 25
italica ... 25
saratogana ... 25
triangularis ... 25
saratogana, Saracenaria ... 25
scapha, Nonionina ... 48
scorpiurus, Reophax ... 4
seligi, Pseudouvigerina ... 35
seligi, Uvigerina ... 35
semicomplanata, Spiroplectammina ... 8
semicomplanata, Textularia ... 7
semiinterrupta, Lagena sulcata ... 14
seminulum, Quinqueloculina ... 13
seminulum, Serpula ... 13
Serpula ... 13
sulcata ... 13, 14
seminulum ... 13
silicula, Hemicristellaria ... 18
silicula, Marginulina ... 18
siliqua, Marginulina ... 19
simondsi, Citharina ... 26
simondsi, Vaginulina ... 26
Siphogaudryina ... 9
Siphogenerina plummeri ... 35
Siphogenerinoides ... 35
brevispinosa ... 35
plummeri ... 35
Siphonina ... 38
fimbriata ... 38
prima ... 38
sollasi, Vitriwebbina ... 31
soluta, Dentalina ... 20
speciosa, Ellipsonodosaria stephensoni ... 47
speciosa, Stilostomella stephensoni ... 47
sphaeroides, Nonionina ... 49
Spirolina agglutinans ... 6
Spiroplecta ... 7, 39
americana ... 39
biformis ... 7
rosula ... 7
Spiroplectammina ... 7
agglutinans biformis ... 7
anceps ... 8
semicomplanata ... 8
semicomplanata juncea ... 8
Spiroplectoides rosula ... 7
spissocostatus, Lenticulina (Robulus) ... 16
squammosa, Fursenkoina ... 46
squammosa, Virgulina ... 46
Stensioina ... 37
americana ... 37
exsculpta ... 37
stephensoni, Ellipsonodosaria ... 47
stephensoni, Gaudryina (Siphogaudryina) ... 9, 10
stephensoni speciosa, Ellipsonodosaria ... 47
stephensoni speciosa, Stilostomella ... 47
stephensoni, Stilostomella ... 47
Stilostomella ... 47
alexanderi ... 47
alexanderi impensia ... 48
rugosa ... 47
stephensoni ... 47
stephensoni speciosa ... 47
striata, Guembelina ... 39
striata, Heterohelix ... 39
striata, Textularia ... 39
strigillata, Vaginulina (Citharina) ... 26
subcarinatus, Cibicides ... 51
subornata, Bulimina ... 36
subperuviana, Pulvinulinella ... 50
subplumoides, Vaginulina ... 26
subrostratum, Loxostomum ... 33
subsphaerica, Globulina lacrima ... 30
subsphaerica, Polymorphina ... 30
sulcata, Lagena ... 13, 14
sulcata semiinterrupta, Lagena ... 14
sulcata, Serpula (Lagena) ... 13, 14
taylorensis, Textularia ... 40
tenuistriata, Uvigerina ... 35
texana, Reophax ... 5
texana, Trochammina ... 8, 9
texanum, Chrysalogonium ... 23
texanus, Ammobaculites ... 7
Textularia ... 7
agglutinans biformis ... 7
carinata expansa ... 8
conulus ... 12
globifera ... 39
globulosa ... 39, 42
quadrilatera ... 33
semicomplanata ... 7
striata ... 39
taylorensis ... 40
triangularis, Cristellaria ... 25
triangularis, Saracenaria ... 25
tricarinata, Tritaxia ... 11
trigona, Allomorphina ... 48
trilatera, Clavulina ... 11
trilaterus, Clavulinoides ... 11
trilaterus concavus, Clavulinoides ... 11
trilobata, Vaginulina ... 18
Tritaxia tricarinata ... 11
Trochammina ... 8
gyroides ... 9
inflatus ... 8
texana ... 8, 9
Truncatulina ... 50
beaumontiana ... 51
ripleyensis ... 50
tuberculata, Vitriwebbina ... 32
Tubitextularia ... 40
bohemica ... 40
cretacea ... 40
tumida, Pulvinulina menardii ... 44
Uvigerina ... 35
cristata ... 35
seligi ... 35
tenuistriata ... 35

Vaginulina 25
barcoensis 26
cretacea 25
gracilis cretacea 25
legumen 25
multicostata 26
navarroana 27
simondsi 26
strigillata 26
subplumoides 26
trilobata 18
webbervillensis 27
Valvulinerina cretacea 37
Valuvulineria nelsoni 45
varians, Pseudotextularia 40, 41
Ventilabrella 42
austinana 42
carseyae 42
eggeri 42
eggeri glabrata 42
plummerae 39, 42
vertebralis austinensis, Nodosaria 22
vertebralis, Dentalina 22
vertebralis, Nautilus (Orthoceras) 22
vertebralis, Nodosaria 22
Virgulina 46
navarroana 46
squammosa 46
Vitriwebbina 31
biosculata 31
chapmani 32
sollasi 31
tuberculata 32
watersi, Plectina 12, 13
webbervillensis, Citharina 27
webbervillensis, Vaginulina 27
zippei, Nodosaria 22

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STUDIES ON TERTIARY AND RECENT GIANT LIMIDAE

HAROLD E. VOKES
PROFESSOR OF GEOLOGY
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CONTENTS

	Page
ABSTRACT	75
I. A NEW SPECIES OF *ACESTA* FROM THE GULF OF MEXICO	75
Genus *Lima* Bruguière, 1797	75
Subgenus *Acesta* H. and A. Adams, 1858	76
Lima (*Acesta*) *bullisi,* new species	77
II. A CATALOGUE OF THE DESCRIBED RECENT AND TERTIARY SPECIES OF *ACESTA*	78
Recent species	78
Recent species incorrectly referred to *Acesta*	85
Tertiary species	85
III. *PLICACESTA,* A NEW SUBGENUS OF *LIMA*	90
Plicacesta, new subgenus	90
LITERATURE CITED	91

ILLUSTRATIONS

PLATE 1: *Lima* (*Acesta*) *bullisi* H. E. Vokes, new species	79
PLATE 2: *Lima* (*Acesta*) *bullisi* H. E. Vokes, new species	81

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STUDIES ON TERTIARY AND RECENT GIANT LIMIDAE

HAROLD E. VOKES
PROFESSOR OF GEOLOGY
TULANE UNIVERSITY

ABSTRACT

A new species, *Lima* (*Acesta*) *bullisi,* is described from 300 and 600 fathoms off Mobile Bay, Alabama. This represents the first reported occurrence of the subgenus *Acesta* in the western Atlantic and contiguous basins. A catalogue of the described Tertiary and Recent species of *Acesta* lists 13 known Recent species [*L.* (*A.*) *butonensis* Bartsch is considered to be a synonym of *celebensis* Bartsch], and 31 species and varieties from the Tertiary deposits of North America, Asia, New Zealand, and Europe. A new subgenus, *Plicacesta,* is proposed for the plicately ribbed *Lima smithi* Sowerby of Japan, and three Asiatic Tertiary species are also referred to it.

I. A NEW SPECIES OF *ACESTA* FROM THE GULF OF MEXICO

Mr. Harvey R. Bullis, Jr., director of the Pascagoula, Mississippi, Station of the United States Fish and Wildlife Service, recently called to my attention two, unfortunately broken, right valves of a species of *Lima* (*Acesta*). These had been obtained in a trawl made by the Fisheries M/V *Oregon* on September 24, 1955, in the Gulf of Mexico at *Oregon* station 1426, 29°17′ north latitude, 87°54′ west longitude, or approximately 70 miles south-southeast of the entrance to Mobile Bay, Alabama. The depth at this station was 600 fathoms, the bottom of mud.

On learning that representatives of this subgeneric group had not been reported from the western Atlantic or contiguous waters, Mr. Bullis kindly granted permission to study and describe the specimens, and thus to record the occurrence of the subgenus *Acesta* in the fauna of the Gulf of Mexico.

Family LIMIDAE

Genus LIMA Bruguière, 1797

Lima BRUGUIÈRE, 1797, Tabl. Encycl. Méth., Vers Coq., **2**, p. 206.
Lima CUVIER, 1798, Tabl. Elem., p. 421.
Lima LAMARCK, 1799, Mem. Soc. d'Hist. Nat. de Paris. **1**, p. 88.
Mantellum ROEDING, 1798, Mus. Bolt., p. 160.
Limaria LINK, 1807, Beschr. Naturallen-Samml., Univ. Rostock, p. 157.
Radula MÖRCH, 1853, Cat. Conch. Yoldi, **2**, p. 57.

Type species, by subsequent tautonomy (Lamarck, 1801) *Ostrea lima* Linnaeus, 1758 = *Lima squamosa* Lamarck, 1801; Recent, apparently world-wide in warmer waters (see discussion, below).

In 1948 the International Commission on Zoological Nomenclature and the Section on Nomenclature of the Thirteenth International Congress of Zoology adopted an amendment to Article 25 of the International Rules providing that a generic name published prior to 1931 on a legend to a plate or plates, and without further explanatory matter, was to be treated as having been published with an "indication" for the purposes of Article 25. This made available the long-used but extra-legal names first used as plate legends in the volumes of the "Tableau Encyclopédique et Méthodique . . ." prepared by Bruguière and not formally diagnosed by him prior to his death in Italy while returning from an expedition to the Near East. The sense of this provision has been embodied in the new (1961) "International Code of Zoological Nomenclature" in Article 16,a,vii, which states that an "indication" includes "the publication of a new genus- or species-group name in connection with an illustration."

This provision validated the generic name *Lima* as used by Bruguière in 1797 as the heading to plate 206 with figures of six species assigned to the genus. The species shown in figure 4 has been identified as that which had been named *Ostrea lima* by Linnaeus (1758, p. 699). Iredale (1939, p. 385) and Dodge (1952, p. 187) state, therefore, that *Ostrea lima* is the type species of *Lima* Bruguière by absolute tautonomy. However, since Bruguière cited no species by name it is not possible to fix the type by reference to the original publication alone, for the identification of the figure concerned is based on the decision of subsequent au-

thors, rather than of the author of the work in question.

Cuvier used *Lima* as a generic name in 1798, with *Lima alba* Cuvier as the sole species, but with *Ostrea lima* Linnaeus in its synonymy. There was, however, no reference to the work of Bruguière; hence, although *Lima* Cuvier is an absolute synonym of *Lima* Bruguière, its proposal cannot be held to have established the type of the Bruguière genus. Similarly, Lamarck in 1799 proposed *Lima* as a generic name, citing *Ostrea lima* as sole example, and hence type by monotypy. But here again there was no reference to earlier usages of the name in a generic sense. In 1801, Lamarck (p. 136) described the species *Lima squamosa,* and cited as illustrations of that form, Bruguière's figure 4 and the same figure in d'Argenville that had been given by Linnaeus as illustrative of his *Ostrea lima.* This combination of references served both to identify the Bruguière figure and to validate the tautonomy involved thus fixing *O. lima* Linnaeus as type of *Lima* Bruguière. Subsequently, according to Stewart (1930, 124), Latreille in 1804 designated *Ostrea lima* as type of *Lima* Bruguière.

While the original description of the species *Ostrea lima* and the cited d'Argenville figure leave little doubt as to the group of species to be included within the genus *Lima* s.s., there is a considerable degree of uncertainty as to the exact form encompassed within the specific name *Lima lima.* This uncertainty likewise results in confusion as to the geographic distribution of the typical species. Linnaeus gave the "habitat" of his species as "In O. Meridionali" a statement which is, as noted by Dodge (1952, 186), "almost completely uninformative." The confusion is, indeed, almost as old as the species itself. Chemnitz (1784, 349) lists *Ostrea lima* in the synonymy of his mononomial *"Radula"* giving the locality as Tranquebar and the Red Sea; but Lamarck (1801, 136) located his *Lima squamosa* as from American waters. Among more recent authors, some, including Woodring (1925, 79), Grant and Gale (1931, 239), and Prashad (1932, 121) give *Lima lima* an Indo-Pacific distribution; others, including Bucquoy, Dautzenberg and Dollfus (1887, 51), Woodring (1938, 48, fft. 58a), and Iredale (1939, 384) cite it as exclusively from the Mediterranean Sea and the western Atlantic Ocean. Lamy (1930, 101) and Abbott (1954, 170) indicate that the species is of world-wide distribution—in tropical waters according to Abbott—but with a wider range from Japan and the Mediterranean Sea on the north to the southern coasts of Australia on the south, according to Lamy. The latter, however, recognizes a number of "forme" of the species within this range.

The form, or forms, included by the various authors within this group, are all moderately large solid shells with, on the main body of the shell, about 18 to 20 strong radiating ribs covered by large, elevated scales. The submargins are marked by numerous much weaker radial riblets.

Subgenus ACESTA H. and A. Adams, 1858

Acesta H. & A. ADAMS, 1858, Genera Recent Mollusca, **2,** p. 558.
Callolima BARTSCH, 1913, U. S. Natl. Mus., Proc., **45,** p. 235.

Type species, by monotypy, *Lima "excavata* (Chemnitz)"= *Ostrea excavata* Fabricius; Recent, 150 to 1,450 fathoms, coast of Norway to the Azores Islands (Thiele, 1918); Greenland to Canary Islands and "à l'ouest du Soudan" (Lamy, 1930).

H. and A. Adams when erecting the subgenus *Acesta* referred to it only the species "*excavata* Chem." This species was variously given in Chemnitz (1784, bd. 7): as *Concha excavata* on page 267, and as *Excavata Fabricii* and *Ostrea excavata* on page 355. It was figured on plate 68, figure 654, "an den norwegischen Stranden", and is the species earlier described from the same area by J. C. Fabricius (1779, 368) as *Ostrea excavata.*

The animals referred to this subgenus have relatively large but comparatively thin shells with a cardinal area that is narrower than that of *Lima* (*Lima*) and is situated mainly posterior to the umbones. The anterior auricle is greatly reduced through the encroachment of the excavate lunule. The posterior position of the cardinal area results in the development of a markedly oblique ligamental pit. The ornamentation of weak, rather irregular radial ribs is more strongly developed on the anterior and posterior portions of the valves, but is fine to almost obsolete on the medial portions of the surfaces where it has an aspect suggestive of shallowly impressed, irregular grooves, rather than of true ribs.

The weak ornamentation and the strongly oblique ligamental pit serve at once to distinguish *Acesta* from *Lima* s.s.

LIMA (ACESTA) BULLISI H. E. Vokes, new species

Plates 1, 2

The two right valves that constitute the available representatives of this species are, unfortunately, both broken. The more complete specimen has been selected as the holotype. It is broken ventrally and the surface is considerably eroded. When received it had numerous worm tube and bryozoan incrustations, and obviously had lain as a dead shell upon the bottom for a considerable period of time. The second specimen, the paratype, is broken both antero-ventrally and ventrally so that little more than one-half of the original valve remains. It is, however, much fresher than the holotype, with a relatively glossy, yellow surface to the valves and only a minimal degree of incrustation by worm tubes. The broken surfaces are relatively fresh and it is possible that the damage occurred in the trawl.

Surprisingly, as restored by growth lines, etc., both specimens are almost identical in size, and hence may be considered as indicating the normal adult size of the species. As restored the species has a height of approximately 111 millimeters, and a width of approximately 92 millimeters. The holotype has an incomplete height of 94 mm, a width, incomplete, of 89 mm, and a semi-diameter of 23.5 mm; the paratype is 105 mm high (incomplete), and has a semi-diameter of 28.3 mm. The width of 70 mm is too incomplete to be of significance. Despite the relatively large size of the specimens, the shell material is exceedingly thin, being but 0.8 mm thick on the median portion of the paratype, and 0.5 mm on the broken ventral median part of the holotype. The latter may have been thinned, however, by erosion or partial solution while lying on the sea floor.

As compared to other described species of *Acesta* the present form is of but moderate size, and is somewhat more ovate and equilateral in outline, but, due to the reduction of the anterior auricle, much more inequilateral than species referred to other subgenera of *Lima*. The umbones are low, eroded, and situated near the anterior end of the relatively short and straight hinge line. The strongly curved ligamental pit varies in size, its greatest width being approximately one-third the total length of the hinge line of the paratype, and but slightly more than one-quarter that length in the holotype; in both specimens the hinge line is 32 mm. long. An elongate and excavate lunular area lies below the beaks, its surface finely radiately sculptured and delimited from the rest of the valve area by the strongest radial riblet present on the entire surface of the shell. The antero-dorsal slope of the valve is oblique, straight to slightly concave, proportionately short; the anterior, ventral and posterior margins are broadly and regularly rounded, the posterior straightening to the short, straight dorsal margin. The junction of the posterior and dorsal margins is moderately to strongly angulate. Exterior sculpture is that characteristic of the subgenus, with numerous radial ribs, very fine along the medial portion of the valve surface, nearly obsolete on the umbo, but becoming coarser toward the margins, especially anteriorly and posteriorly. The first three or four ribs posterior to the lunule are the strongest on the entire valve, other areas with 8 or 9 irregularly developed, rather wavy ribs per centimeter. The ribs increase in number mainly through bifurcation with the development of a median groove on the surface; but occasional increase by intercalation may be observed. On the holotype there is a tendency for the ribbing on the posterior and postero-ventral slope to have each eighth or ninth rib broader, but not higher than the others, and hence the stronger rib does not become a pronounced surface feature.

The interior of the valve is white, with the inner margins apparently smooth (although they may be slightly worn on both specimens.) The adductor impression is relatively small, situated rather high in the valve and at approximately the posterior third of the valve width.

Lima (*Acesta*) *bullisi*, new species, differs from *L.* (*A.*) *excavata* (Fabricius), the type of the subgenus, and the only other species of the group yet reported from within the Atlantic basin waters, in having a shell that is proportionately much broader in comparison with its height, and in the more equilateral and less deeply impressed lunule. The radial ornamentation, though finer, is more strongly developed and the ribs much more numerous.

Among the Pacific Ocean species from American waters, the new species differs from *L.* (*A.*) *mori* Hertlein (1952, 378-80, pl. 20, figs. 12, 13) from Mulberry Seamount off California, in its much sharper, less inflated umbone and proportionately more elongate, less rotund shell outline. *L.* (*A.*) *agassizii* Dall (1902, 16; 1908, 407, pl. 16, fig. 1) from the Gulf of Panama, has a proportionately higher shell with an almost straight anterior end, and, so far as can be judged from Dall's figure, has broader and apparently more strongly developed radial ribbing.

While the present manuscript was in the hands of the editor a complete, but unfortunately pathologic, specimen was received from Mr. Bullis. This had been trawled on

August 26, 1962, at *Oregon* Station 3741, depth 300-340 fathoms, at 29°10′ North latitude and 88°01.5′ West longitude, about 75 miles due south of the entrance to Mobile Bay. Information as to bottom temperature and bottom sediment type are not available.

The specimen, which was alive when taken, had suffered serious damage to the shell and mantle in the region of the lunule at a time when the animal was approximately half grown. This has resulted in a strong in-bending of the lunular area and the development of an open gape in this region (see plate 2, fig. 2). The shell material is thickened and rather rugose and the lunule projects into the main shell cavity in an abnormal manner (pl. 2, fig. 3). Because of this damage the incomplete original specimen is retained as holotype to typify the species despite its worn and broken condition, since it better illustrates the normal form of the shell than does the present distorted specimen.

The height of the shell is 96.8 mm, the width 92.6 mm, and the paired valves have a diameter of 51.5 mm. It is, therefore, slightly wider than the holotype but the height is approximately 18 mm less than the restored height indicated by the original specimens. This apparent difference seems to be due, in part at least, to the injury suffered by the shell, since the width is a little increased by a slight "pouting" of the anterior margin immediately adjacent to the damaged lunular area. Growth lines suggest that the relative height-width proportions were more nearly in accord with those of the holotype during stages of development prior to the injury.

The ornamentation of the valves agrees in all details with that exhibited by the original specimens except in the region immediately adjacent to the lunular area. Here the ornamentation of the younger stages of development is normal in all respects, but that formed after the injury shows radial ribbing that is somewhat stronger and more thread-like with unusually widened interspaces. The hinge area agrees with the previous specimens in all respects and, in addition shows a thin band of lamellar ligament occupying the cardinal margins on each side of the impressed ligamental pit; the latter appears to contain only fibrous ligament. The inner margins of the valve are smooth with the shell thinned to the degree that it is transluscent at the immediate edge. The adductor scar is somewhat larger and very slightly impressed, in contrast to that on the uninjured specimens where it is not impressed and rather difficult to distinguish.

II. A Catalogue of the Described Recent and Tertiary Species of *ACESTA*

During the course of the investigations preparatory to the description of *Lima (Acesta) bullisi* a considerable amount of information was accumulated concerning previously described species of the subgenus, Recent and fossil. No catalogue of these forms has been published. Thiele (1918) discussed the then known Recent species, and Woodring (1938, 14) gave a table of the dredging records available to him. More recently Oyama (1943) discussed (in Japanese) and figured the known Tertiary and Recent species from eastern Asia. It was decided, therefore, to supplement the information available and to prepare a catalogue of the described Recent and Tertiary species referable to the subgenus *Acesta.* This is a result of a canvass of the literature and it is quite possible that some species, especially in the fossil record, have been overlooked; however, it is believed that the following list is essentially complete so far as the described species are concerned, but no attempt has been made to recover all distributional records for these forms and the information here given must be considered as being representative, but not definitive in this respect.

Recent Species

1. Atlantic Basin Area

Lima (Acesta) excavata (Fabricius)

Ostrea excavata Fabricius, 1779, Reise Norwegen, p. 386.

Lima excavata (Gmelin). Lamarck, 1819, Anim. s. vert., **6**, p. 158.

Radula (Acesta) excavata (Chemnitz). H. & A. Adams, 1858, Gen. Recent Mollusca, **2**, p. 558.

Lima (Mantellum) excavata (Fabricius). Jeffreys, 1879, Zool. Soc., London, Proc., p. 564.

Lima (Acesta) excavata (Chemnitz). Philippi, 1900, Zeitsch. Deutsch. Geol. Geselesch., **52**, p. 630, pl. 24, fig. 5.

Lima (Acesta) excavata (Fabricius). Thiele, 1918, Syst. Conchylien-Cab., (N.F.), **7** (2a), Fam. Limidae, p. 19, pl. 1, fig. 4; pl. 3, fig. 13.

Plate 1

Figs. 1-4. *Lima (Acesta) bullisi* H. E. Vokes, n. sp. (X1). Exterior and hinge views of the holotype, USNM 639045 (figs. 1, 2) and of the paratype USNM 639046 (figs. 3, 4). Figure 3 shows the outline of the valve as restored from the two specimens.

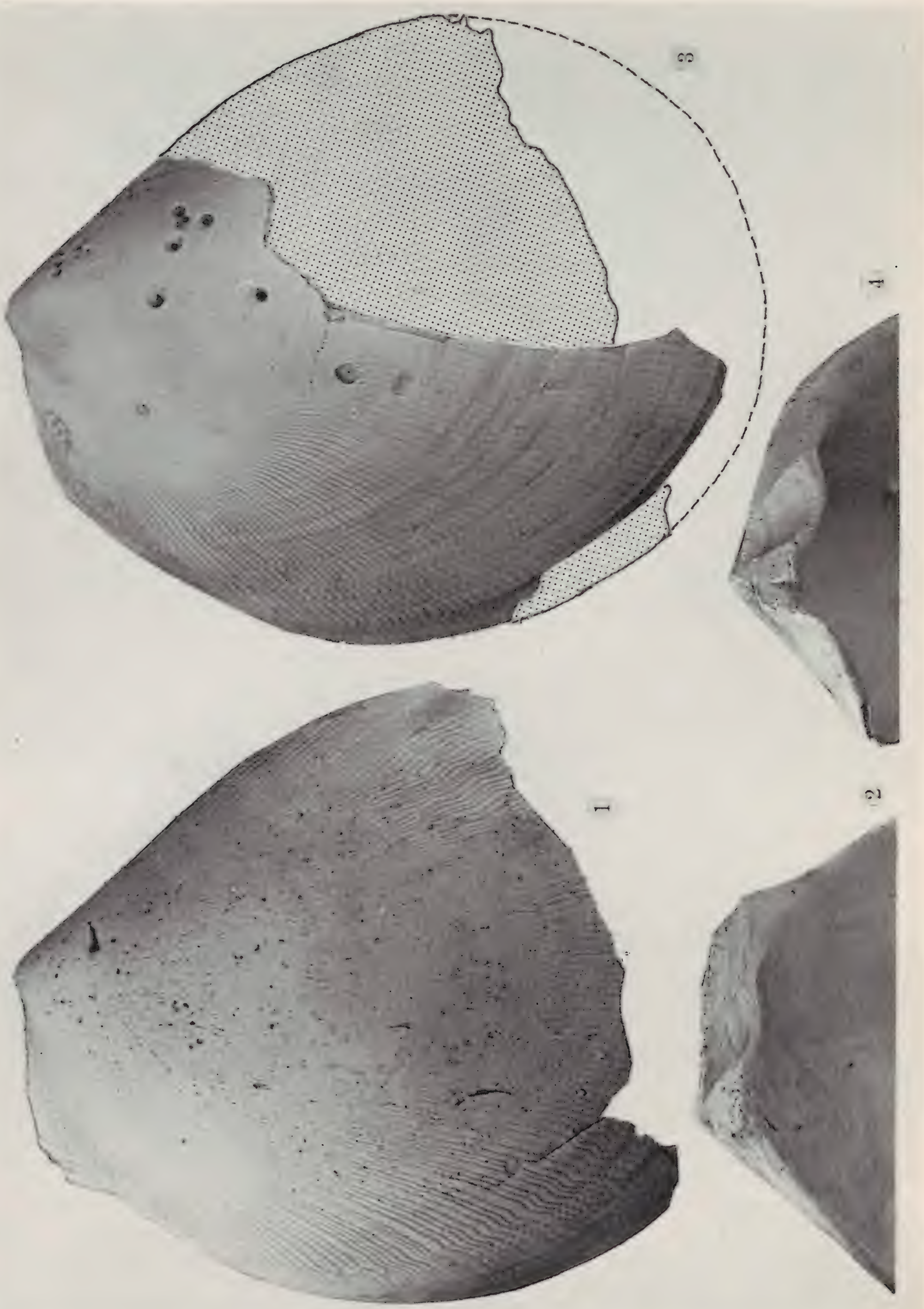

PLATE 1

Range: This species, the type of the subgenus, was described as "an den norwegischen Stranden" (see Chemnitz, 1784, **7**, pl. 68, fig. 654), but subsequent authors have indicated a greater depth range. Lamy (1930, 188) states: "Cette espèce, presque littorale dans les mers du Nord (Norvège), a été signalée aux Açores et près de Ténérife à des profondeurs dépassant 2,000 metres." Later he adds, for the north, records from Iceland and Greenland, and at the south, "dragages de 'Talisman' (1883) à l'ouest du Soudan." Other northern records are given by MacAndrew (1857, 112) who states that it occurs from "North Drontheim to Finmark" in 50 to 150 fathoms. Dall, (1902, 16) records it from "Norway (150-300 fms.)". Thiele (1918, 20) gives the range as from Norway to the Azores in 150 to 1450 fathoms.

Size: The largest specimen reported (Smith, 1899, 251) is 170 mm in height and 125 mm in width. Dall (1902, 16) lists a specimen "Alt. 100; Lat. 106; diam. 55 mm." while MacAndrew (1857, 112) reported "one specimen, living, 5½ by 4¼ in." [ca. 140 X 108 mm]. Bartsch's record (1913, 236): "Alt. 170, lat. 125, diam. 55 . . .", although credited to Dall, 1902, appears to be a combination of the measurements of Smith and Dall cited above.

Ecologic Information: MacAndrew (1857, 112) reports that this species "adheres by a small byssus" to stones on the sea bottom, and Jeffreys (1879, 564-5) states: "Herr Friele informs me . . . that *excavata* attaches itself by a strong byssus to rocks close to the shore." I have found no records suggesting this byssiferous attachment for other species of *Acesta*.

Little temperature information is available for stations from which this species has been taken. Available hydrographic data suggest possible temperatures of approximately 43.5° F. for 150 fathoms off Norway, and of approximately 37.5° F. for 1450 fathoms off the Azores. Shallower water temperatures in the northern seas would be lower than the 150 fathom figure, and the 43.5° temperature may be an upper limit for the species. It is apparent that *L. excavata* furnishes another example of those species whose depth distribution is a function of temperature control.

Lima (Acesta) bullisi H. E. Vokes

Information concerning this species, now known from 300 to 600 fathoms, is given above, in the introduction to the paper and the description of the species.

2. Eastern Pacific Ocean

Lima (Acesta) agassizii Dall

Lima agassizii Dall, Nautilus, **16**, (2), p. 16.

Lima (Acesta) agassizii Dall, 1908, Harvard Coll., Bull. Mus. Comp. Zool., **43** (6), p. 407, pl. 16, fig. 1.

Range: The single known right valve representing this species was dredged from 322 fathoms in the Gulf of Panama.

Size: "Alt. 97; lat. 78; diam. 30 mm." (Dall, 1902).

Ecologic Information: Bottom, green mud (Woodring, 1938, 14); bottom temperature 47° F. (Dall, 1908).

Lima (Acesta) mori Hertlein

Lima (Acesta) mori Hertlein, 1952, Calif. Acad. Sci., Proc., (4) **27**, 379, pl. 20, figs. 12, 13.

Range: The holotype right valve and a fragment of a left valve, presumably the opposite valve of the type, were dredged from the Mulberry Seamount, Lat. 37°26.5′ N., Long. 123°28.7′ W., off San Mateo County, California, in 690 to 800 fathoms. Other specimens have not been recorded.

Size: "Dimensions (ventral margin incomplete); height, 61.8 mm; length, 55 mm; convexity (one valve), 15.8 mm; length of hinge, 15.5 mm; length of anterior umbonal ridge, 23 mm." (Hertlein, 1952).

Ecologic information: The dredge indicated a bottom of rock and shells. No temperature data have been given for this Mulberry dredging, but "Albatross" stations in the general vicinity (dredging station 3104, 37°23′ N., 123°08′ W., depth 391 fathoms, bottom temperature 40.8° F., and hydrographic station 2163, 37°48.5′ N., 123°30.3′ W., depth 900 fathoms, bottom temperature 36.8° F.) suggest bottom temperatures of about 38° F. at the *Lima* locality.

Lima (Acesta) patagonica Dall

Lima goliath Sowerby. Smith, 1885, Voy. H.M.S. "Challenger", Zool., **13**, p. 290 [part].

Lima patagonica Dall, 1902, Nautilus, **16**, (2), p. 16 [non *L. patagonica* von Iher-

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Plate 2

Figs. 1-4. *Lima (Acesta) bullisi* H. E. Vokes, n. sp. (X1). Exterior and hinge views of the left valve of the pathologic hypotype, USNM 639047 (figs. 1, 3), and a dorsal view of the paired valves of the same specimen (fig. 2). Note the great distortion of the lunular area resulting from the injury during growth. Fig. 4 is a dorsal view of the holotype, USNM 639045, for comparison.

PLATE 2

ing, 1907, Anales Mus. Nac. de Buenos Aires, p. 262, pl. 9, fig. 60].
Lima (Acesta) patagonica DALL, 1908, Harvard Coll., Bull. Mus. Comp. Zool., **43**, (6), p. 407.

Range: Dall in his original description of this species recorded it as from the "West coast of Patagonia (245-481 fms.)". The 245 fathoms record is apparently from Smith's report of a specimen, determined as *Lima goliath* Sowerby, taken by the "Challenger" at that depth. Later, in 1908, Dall gave the species as from two "Albatross" localities at 348 and 449 fathoms, respectively, and Woodring, (1938, 14) records an additional specimen from 258 fathoms. I have not found the record upon which Dall based his report of 481 fathoms as the greatest depth.

Size: In the original description of this as yet unfigured species Dall gave dimensions as follows: "Alt. 100; Lat. 72; diam. 31 mm.". This constitutes the only published set of measurements for the species, although Smith (1885, 290) indicates that the "Challenger" specimen was somewhat less than two inches high.

Ecologic information: According to Woodring (1938, 14) the bottom sediment at all "Albatross" stations from which Dall's original specimens were secured was "blue mud", and Smith (1885, 24) indicates the same type of bottom at "Challenger" station 311 from which the specimen reported as "*goliath*" was obtained. Bottom temperatures at the stations from which this species has been obtained range from 46° F. ("Challenger", Stn. 311, 245 fms.) to 50° F. ("Albatross" Stn. 2781, 348 fms.); at "Albatross" Stn. 2785, 449 fms., the deepest confirmed record for the species, the temperature was 47° F.

3. Western Pacific Ocean

LIMA (ACESTA) BARTSCHI Thiele

Lima (Callolima) smithi BARTSCH, 1913, U. S. Natl. Mus., Proc., **45**, p. 236, pls. 12, 13. [non *Lima smithi* Sowerby, 1888]
Lima (Acesta) bartschi THIELE, 1918, Syst. Conchylien-Cab., (N.F.), **7**, (2a), Fam. Limidae, p. 20, pl. 5, fig. 1; pl. 8, fig. 7. [*nom. nov.*]
Lima hughi BARTSCH, 1923, Nautilus, **37**, p. 69-70. [*nom. nov.*]

Range: Bartsch in describing this species reported its occurrence at five dredging stations in the western part of the Philippine Archipelago from north of Mindanao northward to off southeastern Luzon. "It was dredged at depths varying from 281 to 508, or at an average of 401 fathoms." (Bartsch, 1913, 236.)

Size: "The type, which is the largest specimen, measures: alt. 175 mm, lat. 118 mm, diameter 48 mm." (Bartsch, 1913, 236.)

Ecologic information: The species occurs on finely sandy, green to gray mud bottoms. Temperature information for three of the five "Albatross" stations is as follows: off Malavatuan Isl. (13°48.5′ N.; 120°28′40″ E. — the most northern occurrence) 280 fathoms, temp. 46.8° F.; Jolo Sea, south of Cagayan Isl., in 505 fathoms, temp. 49.8° F.; off Balicasag Isl., in southern end of the Bohol Strait, (type locality) in 432 fathoms, temp. 53.3° F. The average temperature is thus about 50° F.

Notes: Oyama (1943, 49, 50) considers that *L. bartschi* is a synonym of *L. philippinensis* Bartsch. Judging from Bartsch's original illustrations, *L. bartschi* is proportionately wider and the postero-ventral margin more obliquely sloping than it is in *philippinensis*. This is more apparent from the illustrations than it is from the comparative dimensions of the two type specimens. Both are of approximately the same height. *Bartschi* is said to be 118 mm wide and this figure is confirmed by measurements of the illustration, but *philippinensis*, which is said to be 111 mm wide, measures on the illustrations only approximately 101 mm in width. This latter figure agrees better with the visual difference between the two specimens. Otherwise, the two forms are strikingly similar in details of ornamentation, hinge structure, etc., and it is possible that larger collections will confirm their identity.

LIMA (ACESTA) BORNEENSIS Bartsch

Lima (Callolima?) borneensis BARTSCH, 1913, U. S. Natl. Mus., Proc., **45**, p. 239, pl. 20, figs. 1, 2.
Lima (Acesta) borneensis Bartsch. THIELE, 1918, Conchylien-Cab., (N.F.) **7**, (2a), Fam. Limidae, p. 25, pl. 7, figs. 8, 9.

Range: The single immature valve upon which this species is based was dredged in 305 fathoms off Silungen Island off the west coast of Borneo.

Size: "The shell measures: alt. 39.2 mm, lat. 33 mm; diameter of the single valve 8 mm." (Bartsch, 1913, 239)

Ecologic information: "Green mud bottom; bottom temperature 43.2°." (Bartsch, 1913, 239)

Note: Though based upon an immature specimen, the wide dorsal area with an umbonal angle between the anterior dorsal and the dorsal margin of almost 140° is sufficient to distinguish it from all other presently described species.

LIMA (ACESTA) CELEBENSIS Bartsch

Lima weberi PELSENEER, 1911, Lamellibranchiata, "Siboga" Exped., (Anat.), p. 33-35. [*nomen nudum*]

Lima (Acesta) celebensis BARTSCH, 1913, U. S. Natl. Mus., Proc., **45**, p. 240, pl. 18 (2 figs.), pl. 19 (2 figs.); PRASHAD, 1932, Lamellibranchiata, "Siboga" Exped., (Systematic Part, **2**,), p. 127, pl. 4, figs. 1-6.

?, *Lima (Acesta) butonensis* BARTSCH, 1913, U. S. Natl. Mus., Proc., **45**, p. 240, pl. 20, figs. 3, 4.

Range: All dredging records of *L. celebensis* are for areas between 5°29′ and 7° 36′ South latitude in the Flores and Banda Seas of the East Indian Archipelago. Bartsch's type came from the Buton Strait, southeast of Celebes, on the north side of the Flores Sea (519 fathoms), while Prashad records it from north of Sumbawa and Lombok Islands in the southwestern part of that sea, as well as northwest of Great Kei Island near the eastern end of the Banda Sea. His depth records range from 487 meters (266 faths.), off Great Kei Isl., to 794 meters (434 faths.), north of Sumbawa Isl.

Size: The type specimen is badly broken and much worn. The height was 159 mm, but other dimensions cannot be determined. The largest specimen recorded by Prashad (1932, 127), from "Siboga" station 316, north of Lombok Isl., 294 fathoms, shows the following dimensions: height 156 mm; width 92 mm; diameter (paired valves) 52 mm.

Ecologic information: No temperature records are available for stations from which *Lima (Acesta) celebensis* has been identified. However, the record for Albatross station 5648, from which the type of *L. butonensis* was obtained in 559 fathoms, is given (U. S. Bur. of Fisheries Doc. 741, 1910) as 59.2° F. This is only a few miles away, and 40 fathoms deeper than the type station (Albatross 5647) for *L. celebensis*. Presumably the bottom temperatures at the two stations were not greatly different.

Bottom sediment at both Albatross stations was green mud. At the Siboga station north of Lombok, where the largest specimen in their collections was obtained, the bottom was of fine, dark brown sandy mud (Tydeman *in* Weber, 1902, App., 16); for the two stations north of Sumbawa, the bottom is reported to have been "fine sandy mud" and "fine grey mud, with some radiolariae and diatoms". At the easternmost station, off Great Kei Island, in the Banda Sea the bottom was "coral sand and dead coral" (Tydeman *in* Weber, 14).

Remarks: Lima (Acesta) butonensis Bartsch was described from a small broken right valve, 26.8 mm high, 22 mm wide and with a diameter of 5.5 mm. It clearly represents an immature individual and there is a most suggestive similarity between Bartsch's original figures and those given by Prashad (1932, pl. 4, figs. 1, 2) of even more immature specimens of *L. celebensis*. In view of this similarity and of the fact that Bartsch's types of the two species are only a few miles apart in Buton Strait and of less than 40 fathoms difference in depth it seems almost certain that *butonensis* represents an immature specimen of *L. celebensis*.

According to Prashad, the forms referred to by Pelseneer in his report on the anatomy of the Lamellibranchiata collected by the Siboga under the name *Lima weberi* represent this species. There was, fortunately, no specific anatomical description of *weberi* by Pelseneer and his name is a *nomen nudum* and can be disregarded.

LIMA (ACESTA) GOLIATH G. B. Sowerby, Jun.

Lima goliath SOWERBY, 1883, Zool. Soc., London, Proc., *1883*, p. 30, pl. 7, fig. 3; DALL, 1902, Nautilus, **16**, (2), p. 16. (belongs to "Section *Acesta*").

Lima (Acesta) goliath Sowerby. BARTSCH, 1913, U. S. Natl. Mus., Proc., **45**, p. 236; THIELE, 1918, Syst. Conchylien-Cab., (N.F.), **7**, (2a), Fam. Limidae, p. 22, pl. 4, figs. 4, 5; OYAMA, 1943, Conch. Asiatica, **1** (1), Fam. Limidae, p. 39, pl. 3, figs. 1a, b; pl. 14, fig. 8.

Range: Sowerby's description gave only "Japan" as the locality for this species. More recently Kuroda and Habe (1952, 22) indicate the range as between 35° and 40° N. lat. on the Pacific side of the Island of Honshu, and between 35° and 42° N. lat. on the Japan Sea. Included within these limits are the more or less north-south trending eastern side of Honshu from Sagami Bay northward, and most of the western side of that island plus the southernmost part of Hokkaido in the Japan Sea. With respect to depth distribution Yamamoto and Habe (1958, 17) state: "This is apparently a deep water species, . . . the bathymetric records of the collected shells, though not alive, ranging from 30 m to 1417 m." [=16 to 775 fathoms]. The latter depth is the Challenger record of a specimen from 34°58′ N., and 139°29′ E., in Sagami Bay. There is, however, some evidence suggesting temperature controls of the depth distribution of this species, as there is for *L. excavata* (see above). Nomura and Hatai (1936, 254) report that in the Tugaru Strait between Honshu and Hokkaido the species occurs between 90 and 123 meters [49 to 67 fthms.] while between Sado Island and the Oga Peninsula, approximately four and a half degrees of latitude to the south, the range was (1936, 260) 117 to 338 meters [64 to 185 fthms.]

Size: Sowerby recorded the dimensions of his type specimen as "Long. 150, lat. 110

mill." The largest Recent specimen that I have found reported in the literature is that figured by Hirase (Taki Ed., 1951, pl. 16, fig. 4) which is reported as being 176 mm high, 124 mm wide, and 53 mm in diameter.

Ecologic Information: The Challenger specimen was reported as having been dredged from a green mud bottom with the bottom temperature being 37.6° F.

LIMA (ACESTA) PHILIPPINENSIS Bartsch

Lima (Callolima) philippinensis BARTSCH, 1913, U. S. Natl. Mus., Proc., **45**, p. 237, pls. 14, 15.

Lima (Acesta) philippinensis Bartsch. THIELE, 1918, Syst. Conchylien-Cab., (N.F.), **7** (2a), Fam. Limidae, p. 24, pl. 7, fig. 1; pl. 8, fig. 3.

Range: Lima (Acesta) philippinensis appears to have been based upon a single, rather well preserved left valve dredged at "Albatross" Stn. 5373, off the outer Tayabas Light on the south coast of Luzon between the Island of Marinduque and the Batangas Coast. The depth was 190 fathoms, according to Bartsch, who adds: "sounding not made but taken from chart". Woodring (1938, 14) notes that the label on the specimen reads 338 fathoms, and this same depth is given for the dredging station by the United States Bureau of Fisheries in their "Document 741" (1910).

Size: According to Bartsch the type measures: "alt. 177 mm, lat. 111 mm; diameter 37 mm", but, as noted above in the discussion of *Lima bartschi,* the width is more probably 101 mm.

Ecologic Information: The bottom sediment at the type locality was gray mud. Bottom temperature according to "Document 741" was 51.8° F.

LIMA (ACESTA) RATHBUNI Bartsch

Lima crocea PELSENEER, 1911, Lamellibranchiata, "Siboga" Exped. (Anat.), pp. 33, 34 [*nomen nudum*].

Lima (Callolima) rathbuni BARTSCH, 1913, U. S. Natl. Mus., Proc., **45**, p. 237, pls. 15, 16.

Lima (Acesta) rathbuni Bartsch. THIELE, 1918, Syst. Conchylien-Cab., (N.F.), **7** (2a), Fam. Limidae, p. 23, pl. 6, fig. 1, pl. 8, fig. 1; PRASHAD, 1932, Lamellibranchiata, "Siboga" Exped., (Systematic Part **2**), p. 127.

?, *Lima dalli* PLATT, 1949, Natl. Geographic Mag., **96**, (1), color plate, p. 71, fig. 11.

Range: This appears to be the most widely distributed species of *Acesta* in the tropical western Pacific Ocean. Bartsch recorded it from a number of localities ranging from north of Jolo in the Sulu Archipelago (lat. 6°02′55″ North), northward to the southern coast of Luzon off Outer Tayabas Light, at 13°49′ North. Prashad reports specimens dredged by the "Siboga" Expedition off the Kei Islands Group in the Banda Sea at 5°26′ to 5°40′ South latitude. Bartsch records the depth ranges in the Philippine area as being "from 161 to 226 fathoms, or an average of 194 fathoms", while Prashad records the species from 310 and 397 meters [169.5 and 217 fthms.] or within the depth range recorded for the Philippine specimens.

Size: Bartsch states that the largest specimen obtained by the "Albatross" measures: "alt. 208 mm, lat. 156 mm; diameter 59 mm." This is the largest Recent specimen of *Acesta* for which I have found any record. The type, from 186 fathoms off Jolo Light measures: "alt. 182 mm. lat. 135 mm; diameter 52 mm." The larger of the two specimens secured by the "Siboga" measured 156 mm in height, 119 mm in width, and had a diameter of 51 mm.

Ecologic Information: Four of the eight localities recorded by Bartsch for this species had a bottom sediment of green mud. The two localities reported by Prashad had, according to Tydeman *in* Weber (1902, App., 14), greenish gray mud and gray mud bottoms. Of the remaining four localities, one had fine coral sand, one was *Globigerina* ooze, a third was *Globigerina* and sand, and the fourth had shell and coral bottom. Bottom temperatures ranged from 52.4° F. to 54.3° F. for five stations in the Mindanao Sea between Mindanao and Bohol, and to 57.4° F. for 161 fathoms off Jolo Light in the Sulu Archipelago.

Remarks: According to Prashad the forms referred to by Pelseneer under the specific name *Lima crocea* represent this species. Fortunately, Pelseneer only listed *crocea* along with other forms as exhibiting certain anatomical characters and did not give any specific description by which the form could be distinguished. Hence his name is a *nomen nudum* and can be disregarded.

The beautiful pair of valves figured by Platt in the National Geographic Magazine under the name *Lima dalli* and said to come from the Philippines, appear to represent this species. I have been unable to find any description of an *Acesta*-type *Lima* bearing this specific name.

4. Indian Ocean Species

LIMA (ACESTA) INDICA Smith

Lima indica SMITH, 1899, Ann. & Mag. Nat. Hist., (7) **4**, p. 251; ALCOCK, 1907, Illustr. Zool. "Investigator", Moll., pl. 13, figs. 4, 4a.

Range: This species was described from two possibly somewhat immature specimens

dredged from 430 fathoms off the Travancore coast, near the southwestern end of the Indian peninsula.

Size: The larger specimen had a length of 75 mm; a width of 61 mm, and was 34 mm in diameter. The smaller specimen was 51 mm in length; other dimensions are not given.

Ecologic Information: Bottom sediment at the type locality was gray mud; temperature data are not available.

Lima (Acesta) niasensis Thiele

Lima (*Acesta*) *niasensis* Thiele, 1918, Syst. Conchylien-Cab., (N.F.), **7** (2a), Fam. Limidae, p. 23, pl. 3, fig. 3; pl. 4, fig. 12.

Range: This species was described from the "Nias-sud-Kanal". According to Thiele and Jaeckel (1931, 166) the type was dredged in 370 fathoms off the south coast of the Island of Nias, southwest of Sumatra.

Size: The dimensions of the holotype are: height 137 mm; width 101 mm, diameter 47 mm.

Ecologic Information: Not given.

A survey of the available dredging records for the stations from which species of *Acesta* have been recovered indicate that the genus has a depth range from 16 fathoms (shallowest report for *goliath*) to 1450 fathoms (*excavata*); the average of all available record is 336.4 fathoms. The average bottom temperature for all stations from which data were available is 48.4° F. This figure is somewhat high due to the fact that *L. rathbuni* Bartsch, the largest species, appears also to be a warmer water species than the rest, the average for 6 stations for that species being 54.3° F.; without this species the average temperature for all other species is 45.7° F.

That the species of *Acesta* prefer a mud, or fine sand and mud, bottom is well evidenced by the fact that records of bottom sediment for 24 of the localities report "mud" either green, gray, or blue in color. "Green mud" is specified for 13 of these stations, while "gray mud" occurs six times and "blue mud" twice; 3 stations do not report a specific color. There is one record of a *Globigerina* bottom, presumably an ooze, and one of a *Globigerina* and sand. Four stations report sand, or "fine sand"; one "shell and coral"; one "rock, shell", and one record of "stones".

Recent Species Incorrectly Referred to *Acesta*

Woodring (1938, p. 14) has noted that the thick-shelled *Lima* "(*Acesta*)" *diomedae* Dall (1908, p. 407, pl. 7, fig. 2) off a rocky bottom in 385 fathoms near the Galapagos Islands, and *Lima* "(*Acesta*)" *verdensis* Bartsch (1913, p. 239, pl. 20, figs. 5, 6) from green mud and sand in 394 fathoms off Sombrero Island in the Philippines, "apparently do not belong to this group of thin-shelled species." It may be that it will prove necessary to establish a new subgenus to accommodate them.

"*Acesta*" *iwaotakii* Habe (1961, pp. 419, 429, text figs. 3, 4) lacks the oblique ligamental pit of *Acesta*, and is sculptured by divaricate radial ribbing unlike that characteristic of the subgenus. It was compared by Habe with *Lima albimacoma* Dall from the Caribbean Sea, a species that is generally referred to *Ctenoides* Mörch, 1853.

Tertiary Species

As would be expected the deepwater habitat of species of *Acesta* makes them of relatively rare occurrence in the Tertiary fossil record, and the known fossil species all are from tectonically active areas where deeper water deposits have been elevated by faulting. One species is known from the Caribbean region; eleven from the circum-Pacific area including western North America, Japan, the Celebes, and New Zealand; and fourteen species and varieties have been named from the northern portion of the Tertiary Tethyan sea along the Alpine-Carpathian fore-deeps.

1. Caribbean Region

Lima (Acesta) goajira Olsson and Richards

Lima (*Acesta*) *goajira* Olsson and Richards, 1961, Acad. Nat. Sci., Philad., Notulae Nat., no. 350, p. 6, pl. 1, fig. 1.

The type of this species was obtained from limestones of probable upper Oligocene age ten kilometers SSE of Guatchari on the Goajira Peninsula of northeastern Colombia. A second specimen, apparently referable to this species, is in the collections of Dr. Olsson from a locality in Costa Rica. Both are characterized by smooth surface of the valve with fine radial riblets present only near the extreme dorsal margin.

2. Western North America

Lima (Acesta) oregonensis Clark

Lima (*Plagiostoma*) *oregonensis* Clark, 1925, California Univ., Dept. Geol. Sci., Bull., **15** (4), p. 84, pl. 14, figs. 3, 4.

Lima oregonensis Clark. WEAVER, 1943, Washington Univ. [Seattle] Publ. Geol., **5**, p. 99, pl. 22, figs. 2, 6.

Lima (*Acesta*) *oregonensis* Clark. MOORE and VOKES, 1953, U. S. Geol. Survey, Prof. Paper 223-E, pp. 115, 118.

This species appears to be diagnostic of the upper member of the Keasey Formation in northwestern Oregon (see Moore and Vokes, 1953). The strata referred to this member are believed by the present writer to be of lower Oligocene age. Weaver (1943, p. 99) reports that *Lima oregonensis* also occurs "in the Keasey formation near Holcomb in southwestern Washington and in lower Oligocene strata on the south side of Bremerton Inlet." These latter specimens are said to be proportionately higher than those from the type locality.

The type specimens were relatively immature individuals, Clark citing the holotype as: "Length about 63 mm; height about 66 mm." Larger specimens collected by the writer are now in the United States National Museum. The largest, an incomplete cast, has a height of 107 mm, a width of 98 mm, and a diameter (left valve only) of approximately 24 mm; the total height probably did not exceed 115 mm. As suggested by the above dimensions this species has an almost orbicular outline with the height and width closely approximate. In addition to the coarser radial ornamentation near the anterior and posterior margins there are fine incised radial lines present on the mid-area of the valve in the umbonal region; these are absent over the smooth, polished surface ventral to the umbones.

LIMA (ACESTA) ROBERTSAE Durham

Lima robertsae DURHAM, 1944, California Univ., Dept. Geol. Sci., Bull., **27** (5), p. 139, pl. 13, fig. 10.

Described from the "*Echinophoria rex* zone" of the upper Oligocene, Blakeley Formation of Kitsap County, Washington, *Lima robertsae* is distinguished by the possession of "about nine well-defined rounded radial ribs with slightly narrower interspaces, situated on the anterior third of the shell." A few indistinct ribs "may occasionally be seen" on the posterior part of the valves; otherwise the shell is smooth.

LIMA (ACESTA) TWINENSIS Durham

Lima twinensis DURHAM, 1944, California Univ., Dept. Geol. Sci., Bull., **27** (5), p. 139, pl. 13, fig. 11.

Lima twinensis was described from the "*Echinophoria apta* zone", uppermost Oligocene or lower Miocene, of the Twin Rivers Formation in Clallam County, Washington. It is also reported by Durham as occurring in the "*E. rex* zone", upper Oligocene, in the Blakeley Formation in Kitsap County, Washington. It is similar to *Lima oregonensis* Clark in shape and general proportions, but differs in details of ornamentation. Durham thought it more tumid than the Keasey species, but Oregon specimens of comparable size show the same degree of inflation as *twinensis*.

LIMA (ACESTA) HAMLINI Dall

Lima hamlini DALL, 1900, Nautilus, **14**, pp. 15, 16; DALL, 1925, U. S. Natl. Mus., Proc., **66**, art. 17, p. 18, pl. 29, fig. 6.

Lima (*Acesta*) *hamlini* Dall. WOODRING, 1938, U. S. Geol. Survey, Prof. Paper 190, p. 47, pl. 8, figs, 5, 7, 10, 11.

Woodring has given a full discussion of this species from the Pliocene, Repetto Formation of the Los Angeles Basin area in southern California. He also reports a single small crushed right valve from deposits of upper Miocene age. On the basis of available information he concludes (1938, p. 17) that "the fossils of deep-water facies suggest that during Repetto time the Los Angeles Basin sea had depths of 300 to 600 fathoms (roughly 2,000 to 4,000 feet)."

3. Western Pacific: Japan

LIMA (ACESTA) KUMASOANA Nagao

Lima amaxensis Yokoyama *kumasoana* NAGAO, 1928, Tohoku Imp. Univ., Sci. Repts., (2) Geol., **9** (3), p. 104, pl. 20, figs. 31, 31a, 32.

Lima (*Acesta*) *kumasoana* Nagao. OYAMA, 1943, Conch. Asiatica, **1** (1), Fam. Limidae, p. 43, pl. 3, fig. 2; pl. 5, fig. 3.

Judging from the published illustrations the valve surfaces in this species are rather completely covered by irregularly developed surficial radial ribbing similar to that exhibited by *L.* (*Acesta*) *celebensis* Bartsch (1913, p. 240, pls. 18, 19), and quite different from the plicated ribbing that marks *Lima* (*Plicacesta*) *amaxensis* Yokoyama (1911, p. 15, pl. 3, fig. 2).

The lectotype, selected by Hatai and Nisiyama (1952, p. 71), is from the Sakasegawa Formation, upper Eocene of Kyushu, Japan.

?, LIMA (ACESTA) NISHIYAMAI (Yokoyama)

Perna nishiyamai YOKOYAMA, 1911, Coll. Sci., Univ. Tokyo, Jour., **27**, art. 20, p. 7, pl. 1, figs. 1a, 1b.

Lima eocenica NAGAO, 1928, Tohoku Imp. Univ., Sci. Repts., (2) Geol., **9** (3), p. 105, pl. 21, figs. 1-3. [non *Lima miocenica* var. *eocenica* Rovasenda, 1892]

Lima (*Acesta*) *nishiyamai* (Yokoyama). OYAMA, 1943, Conch. Asiatica, **1** (1), Fam. Limidae, p. 40, pl. 3, figs. 3, 4; pl. 4, fig. 1; pl. 14, fig. 9.

Perna ? nishiyamai Yokoyama. MAKIYAMA, 1957, Palaeont. Soc. Japan, Spec. Paper **3** (1), pl. 1, figs. 1a, 1b.

The systematic position of this upper Eocene species from the Island of Kyushu is uncertain. Hatai and Nisiyama (1952, pp. 72, 73, 124) accept, apparently without question, Oyama's assignment of *Perna nishiyamai* Yokoyama to *Lima* (*Acesta*), and also the synonymizing with it of Nagao's *Lima eocenica*. More recently however, Makiyama while refiguring the Yokoyama types makes reference to the assignment to *Lima* (*Acesta*), but without comment, and at the same time refers it to "*Perna ?*".

Published illustrations are inconclusive, although, if the dashed line restoration of the outline of the holotype given by Yokoyama, and reprinted both by Oyama and Makiyama, is correct, the straight posterior dorsal margin is much longer in proportion to the other dimensions of the valves than is characteristic of most species of *Acesta*, and at the same time is more like that found in "*Perna*" (=*Isognomon*).

It may also be observed that there is little other than upper Eocene age to suggest that the crushed and fragmentary specimens upon which Nagao based his *Lima eocenica* are conspecific with "*Perna*" *nishiyamai*.

LIMA (ACESTA) NAGAOI Oyama

Lima goliath Smith [Sowerby]. YOKOYAMA, 1927, Fac. Sci., Imp. Univ. Tokyo, Jour., (2) **2** (4), p. 188, pl. 50, fig. 1.

Lima sp.; cfr *goliath* Sm. [Sowerby]. NAGAO, 1928, Tohoku Imp. Univ., Sci. Repts., (2) Geol., **12** (1), p. 40, pl. 6, figs. 17-19.

Lima (*Acesta*) *nagaoi* OYAMA, 1951, Mineral. & Geol., **4** (1-2), p. 56.

Lima (*Acesta*) cf. *goliath* Sowerby. HATAI and NISIYAMA, 1952, Tohoku Univ. Sci. Repts., (2) Geol., Spec. vol. **3**, p. 72.

Lima nagaoi, from the Oligocene deposits of Nagasaki Prefecture, Kyushu, was distinguished from the typical *L. goliath* by its greater width in proportion to its height. The holotype is the specimen figured by Yokoyama in 1927, (republished by Makiyama 1959, pl. 61, fig. 1 as "*Lima* (*Acesta*) aff. *goliath* Sowerby"). A comparison of this figure with the original illustration of *goliath* appears to justify the separation of *nagaoi*, but the ornamentation, etc., is so similar as to suggest that it may be ancestral to *goliath* which has been reported from the upper Miocene and the Pliocene as well as from the Recent in Japan.

LIMA (ACESTA) J-SUZUKII Takeda

Lima (*Acesta*) *j-suzukii* TAKEDA, 1953, Hokkaido Assoc. Coal Mining Technol., Studies in Coal Geol., **3**, p. 75, pl. 13, figs. 1-4.

The holotype of this elongate-ovate species from the upper Oligocene Poronai Formation of the Island of Hokkaido is the largest Tertiary *Acesta* reported from the Japanese archipelago. Its dimensions are: height 180 mm, width 90 mm, diameter, paired valves, 43 mm.

LIMA (ACESTA) YAGENENSIS Otuka

Lima goliath Sowerby. YOKOYAMA, 1925, Fac. Sci., Imp. Univ. Tokyo, Jour., (2) **1** (3), p. 123, pl. 14, fig. 11; YOKOYAMA, 1925, Coll. Sci., Imp. Univ. Tokyo, Jour., **45** (5), p. 26, pl. 3, figs. 1, 4.

Lima (*Acesta*) *goliath yagenensis* OTUKA, 1939, Geol. Soc., Japan, Jour., **44**, no. 544, p. 27.

Lima (*Acesta*) *yagenensis* Otuka. OYAMA, 1943, Conch. Asiatica, **1** (1), Fam. Limidae, p. 42, pl. 4, fig. 2; pl. 5, fig. 4.

The illustrations of Yokoyama, cited above, show that this species which has been reported from the upper Oligocene and the lower and middle Miocene of Honshu differs from the typical forms of *Lima goliath* in having a greater amount of anteroventral obliquity in the shell together with an apparently more inflated, and hence more pronounced, umbonal area.

LIMA (ACESTA) OMORII Aoki

Lima (*Acesta*) *omorii* AOKI, 1956, Palaeont. Soc. Japan, Tran. & Proc., (N.S.), no. 22, art. 287, p. 189, pl. 29, figs. 1a, 1b, text fig. 2 (7).

Lima omorii, from the Miocene of Honshu, is strikingly orbicular in outline, is almost smooth except for weak radial ribbing near the lateral margins, and is rather more inflated than most species of the subgenus.

LIMA (ACESTA) GOLIATH Sowerby

As noted above (see *Lima nagaoi*, supra), *Lima goliath* the representative of the subgenus *Acesta* in the Recent faunas of the Japanese seas, has been reported from deposits as old as the Oligocene. The older occurrences are now referred to other species, but there are records of the true *goliath* from the upper Miocene and the Pliocene to substantiate its geologic antiquity.

4. Western Pacific: Celebes

LIMA (ACESTA) FULGURANS Martin

Lima fulgurans MARTIN, 1933, Leid. Geol. Med., **6**, p. 14, pl. 1, fig. 1.

Lima (*Acesta*) *fulgurans* Martin. OYAMA, 1943, Conch. Asiatica, **1** (1), p. 51, text fig. 12.

Because of the absence of Recent species in the fauna, Martin assigned an Oligocene age to *Lima fulgurans* and associated forms

from the Sampolakosa beds as exposed in the asphalt quarries at Waisiu on the Island of Buton in the Celebes. More recently, Beets (in Van Bemmelen, 1949, p. 421) has concluded that the results of studies of the corals, diatoms, foraminifera, as well as of more complete molluscan collections, indicate that the fauna is "certainly younger Upper Miocene and possibly Lower Pliocene" in age and that Martin was misled by the unusual deep-water aspect of the fauna represented.

In size, shape, and so far as can be determined from the original illustration, in character and strength of the radial ornamentation, this species is strikingly similar to *L.* (*Acesta*) *celebensis* Bartsch (1913, p. 240, pls. 18, 19) the type of which had been dredged from nearby in the Buton Straits.

5. Western Pacific: New Zealand

Lima (Acesta) levitesta Finlay

Lima laevigata Hutton, 1873, Catal. Tert. Moll. New Zeal., p. 33. [non *Lima laevigata* McCoy, 1844]
Lima levitesta Finlay, 1926, New Zeal. Inst., Trans., **57**, p. 527 (new name pro *laevigata* Hutton).
Callolima levitesta (Finlay). Marwick, 1943, Royal Soc. New Zeal., Trans., **73** (3), p. 182.

This relatively smooth-shelled species was described from the Milburn Limestone, middle Oligocene, of Otago, New Zealand.

Lima (Acesta) regia Suter

Lima (*Plagiostoma*) *regia* Suter, 1917, New Zeal. Geol. Survey, Palaeont. Bull. **5**, p. 70, pl. 9, fig. 1.
Callolima regia (Suter). Marwick, 1943, Royal Soc. New Zeal., Trans., **73** (3), p. 182.

This gigantic species (holotype height 200 mm, width 175 mm, semidiameter 15 mm) appears to represent the largest known *Acesta*. The height of the holotype is exceeded by that of the largest specimen of the Recent *rathbuni* Bartsch (1913, p. 238) which is 208 mm high, but that form has a width of but 156 mm. Marwick reports a single valve from "*Isis* bed, Campbell's Beach, Allday Bay" that measures "190 mm X 155 mm X 45 mm" and suggests that the diameter of the type specimen has been affected by post-depositional compaction.

Suter gave a Miocene age for his type from Seal Rock near Brighton, New Zealand; Marwick (1943, p. 190) gives the age of the *Isis* bed as "Waitakian Stage, Upper Oligocene)."

Lima (Acesta) imitata Suter

Lima imitata Suter, 1917, New Zeal. Geol. Survey, Palaeont. Bull. **5**, p. 70.
Lima (*Acesta ?*) *imitata* Suter, 1917, New Zeal. Geol. Survey, Palaeont. Bull., **5**, pl. 8, fig. 1.
Callolima imitata (Suter). Marwick, 1943, Royal Soc. New Zeal., Trans., **73** (3), p. 182.

In describing his *Lima imitata* Suter noted that it bore "close resemblance" to *Callolima* and *Acesta* "neither of which, however, has been recorded in the fossil stage." He further compared his species with *L.* (*Acesta*) *celebensis* Bartsch and *L.* "(*Callolima*)" *philippinensis* Bartsch, concluding that the shape of the valve and the sculpture suggested the reference of *imitata* to "one of these sections, more especially *Acesta*."

Suter gave a Miocene age for the species.

Lima (Acesta) sp. (Marwick)

Callolima sp. Marwick, 1931, New Zeal. Geol. Survey, Palaeont. Bull. **13**, p. 65, fig. 65.

A relatively small, possibly somewhat immature specimen of *Acesta* has been reported by Marwick (as *Callolima*) from the Ihungia Series of the upper Oligocene, Gisborne District, New Zealand.

6. Europe: Italy

Lima (Acesta) eocenica Rovasenda

Lima miocenica var. *eocenica* Rovasenda, 1892, I fossili di Gassino, pp. 9, 10.
Lima (*Acesta*) *eocenica* (Rovasenda). Sacco, 1898, I Moll. terr. Terziarii Piemonte e Liguria, (25), p. 21, pl. 6, fig. 2.

Lima eocenica Rovasenda is an exceedingly orbicular species that was thought both by Sacco (1898, p. 21) and by Philippi (1900, p. 631) to be, together with the Miocene *L.* (*Acesta*) *postclypeiformis* Sacco, descendants of the Cenomanian, Cretaceous, *clypeiformis* d'Orbigny, a similarly orbicular species that appears to have a small anterior ear. These authors believed that the *clypeiformis - eocenica - postclypeiformis* series represented an evolutionary line distinct from that which produced the *miocenica - excavata* series, derived by Sacco from *Lima undata* Deshayes and *orbignyana* Matheron of the European Cretaceous.

Lima eocenica is reported as rare in the "Calcare de Gassino" in strata correlated with the Bartonian, upper Eocene.

Lima (Acesta) postclypeiformis Sacco

Acesta postclypeiformis Sacco, 1898, I. Moll. terr. Terziarii Piemonte e Liguria, (25), p. 21, pl. 6, fig. 3.

Although this orbicular species from the Aquitainian of Italy is said to be "90 X 90 mm", the original figure suggests that the type is slightly higher than wide.

LIMA (ACESTA) MIOCENICA Sismonda

Lima gigantea BELLARDI, 1839, Soc. geol. France, Bull., **10**, p. 31. [non *Lima gigantea* Gray, 1825, Ann. Phil., **25**, 139]
Lima miocenica SISMONDA, 1842, Syn. meth. Anim. invert. coll. Com. st. Mart. della Motta, p. 22; MICHELOTTI, 1847, Naturk. Verh. Hollandische Maatsch. Wetens. Te Haarlem, **3** (2), p. 12.
Lima (*Acesta*) *miocenica* (Sismond.). SACCO, 1898, I Moll. terr. Terziarii Piemonte e Liguria, (25), p. 19, pl. 5, figs. 23-27.

Acesta miocenica ranges, in its typical form, according to Sacco, from the Tongrian to the Helvetian (Oligocene-middle Miocene) in Italy. The form from the Vienna Basin referred to this species by Hoernes (1867, p. 385, pl. 54, figs. 3a, b) has been distinguished as a variety by Sacco (see below). Other described "varieties" range from the upper Eocene to the Helvetian, Miocene.

LIMA (ACESTA) MIOCENICA Sismonda EOGASSINENSIS Sacco

Lima miocenica Sismonda. ROVASENDA, 1892, I fossili di Gassino, p. 9.
Lima (*Acesta*) *miocenica* var. *eogassinensis* SACCO, 1898, I Moll. terr. Terziarii Piemonte e Liguria, (25), p. 20, pl. 5, fig. 29.

Described from marls associated with limestone at Gassino, Italy, and reported by Sacco as being "frequente". The strata are correlated with the Bartonian, upper Eocene.

LIMA (ACESTA) MIOCENICA Sismonda STRICTA Sacco

Lima (*Acesta*) *miocenica* var. *stricta* SACCO, 1898, I Moll. terr. Terziarii Piemonte e Liguria, (25), p. 19, pl. 5, fig. 28 [*non* 22, as stated, p. 19]

An unusually narrow and elongate form of *miocenica*, which in turn is to be recognized by its elongate-ovate outline as contrasted with the orbicular form of *eocenica* and *postclypeiformis*. The variety *stricta* was described from the Helvetian, Miocene, strata at Rosignano Monferrato, Italy, where it was said to be of "poco frequente" occurrence.

LIMA (ACESTA) INOCERAMOIDES Sismonda MS *in* Sacco

"*Lima* (*Acesta*) *inoceramoides* (*Sismd.*). (*Lima inoceramoides* Sismd. in litt.)" SACCO, 1898, I Moll. terr. Terziarii Piemonte e Liguria, (25), p. 20, pl. 6, fig. 1.

This Italian Oligocene species is somewhat more broadly ovate than the typical representatives of the *miocenica*-group. It is described as concentrically subsquamose, with radial ribbing only near the margins.

LIMA (ACESTA) CRASSICOSTA Seguenza

Lima crassicosta SEGUENZA, 1877, Soc. Malac. Ital., Bull., 1877.
Acesta crassicosta (Segu.). SACCO, 1898, I Moll. terr. Terziarii Piemonte e Liguria, (25), p. 21.

A Pliocene species characterized by somewhat stronger radial ornamentation than that of *excavata*, which was described by Seguenza as from "sedimenti pliocenici depositatisi a grandi profundita."

7. Europe: Vienna Basin

LIMA (ACESTA) MIOCENICA Sismonda COLLIGENS Sacco

Lima miocenica Sismonda. HOERNES, 1867, Abhandl. d. K.-K. geol. Reichsanstalt, Wien, **4**, p. 385, pl. 54, figs. 3a, b.
Lima miocenica var. *colligens* SACCO, 1898, I Moll. terr. Terziarii Piemonte e Liguria, (25), p. 19.

Sacco distinguished this Miocene form from Ruditz, Austria, as a separate variety because the surface of the valve was completely striated and lacked the median smooth area of *miocenica miocenica*.

8. Europe: Hungary

A rather thick series of marls and clays of apparent rather deep-water deposition marks the upper Eocene and Oligocene deposits near Budapest, Hungary. *Acestas* appear to occur at different stratigraphic levels throughout the entire 300 to 500 meters of sediment present. Three species had been described from these beds prior to work of Nozsky (1939). The latter relegated two of these to positions as "varieties" of *miocenica*, while adding three additional "varieties". Unfortunately Nozsky's illustrations are too poor to permit certain conclusions as to the validity of these "varieties" but it seems probable that all of Nozsky's new forms might well be better considered as distinct from the typical Italian form of *miocenica*.

LIMA (ACESTA) HAERINGENSIS Dreger

Lima haeringensis DREGER, 1903, Jahrb. K.-K. geol. Reichsanstalt, Wien, **53**, p. 257, pl. 11, fig. 1.
Lima miocenica var. *häringensis* Dreger. NOZSKY, 1939, Ann. Mus. nat. Hungarici, **32**, pars Min. Geol. et Palaeont., pp. 42, 113.

An almost smooth, elongated upper Eocene or lowermost Oligocene species.

LIMA (ACESTA) MITTERERI Dreger

Lima mittereri DREGER, 1903, Jahrb. K.-K. geol. Reichsanstalt, Wien, **53**, p. 258, pl. 9, figs. 6, 8.

A large, elongate-ovate species, somewhat more anteriorly oblique than *haeringensis*, and readily distinguished from it by the irregular radial ribbing that covers the surface of the valve. Apparently collected from the same geologic horizon as *haeringensis*.

LIMA (ACESTA) SZABOI Hofmann

Lima szaboi HOFMANN, 1873, Hung. geol. Anstalt, Mitt. a Jahrb., (2) **3**, p. 199, pl. 14, fig. 3; GAÁL, 1918, Ann. Mus. nat. Hungarici, **16**, p. 258, fig. 5.

Lima (Acesta) miocenica Sism. var. *szaboi* Hofm. NOZSKY, 1939, Ann. Mus. nat. Hungarici, **32**, pars Min. Geol. et Palaeont., pp. 41, 112.

Described as lower Oligocene, but now thought to be of upper Eocene age, this form was considered as ancestral to *L. miocenica* by Gaál; a conclusion which was accepted by Nozsky, who at the same time, reduced it to the rank of a "variety" of *miocenica*.

LIMA (ACESTA) MIOCENICA Sismonda HANTKENI Nozsky

Lima (Acesta) miocenica Sism. var. *hantkeni* NOZSKY, 1939, Ann. Mus. nat. Hungarici, **32**, pars Min. Geol. et Palaeont., pp. 41, 111, pl. 2, fig. 7.

The illustration of this Rupellian, Oligocene, species is apparently based upon a shaded drawing and it is not possible to judge whether or not the specimen has been in any way crushed or distorted in fossilization. If it has not been altered it represents the most anteriorly elongated form to be referred to *Acesta*, and is clearly to be separated from *miocenica*. If it be measured in conventional style, with the dorsal margin parallel to the dorsal margin of the posterior auricle, the height is approximately 103 mm and the width of the valve 118 mm. These figures contrast with those given by Sacco (1898, p. 19) for typical forms of *miocenica:* "Alt. 20-165 mm; Lat. 13-125 mm."

LIMA (ACESTA) MIOCENICA Sismonda MARGINATOSTRIATA Nozsky

Lima (Acesta) miocenica Sism. var. *marginatostriata* NOZSKY, 1939, Ann. Mus. nat. Hungarici, **32**, pars Min. Geol. et Palaeont., pp. 43, 113, pl. 2, fig. 16.

A broadly orbicular Oligocene species, this "variety of *miocenica*" seems to the writer to be more probably related to the *eocenica-postclypeiformis* series of the Italian authors than it is to *miocenica*.

LIMA (ACESTA) MIOCENICA Sismonda HOFMANNI Nozsky

Lima (Acesta) miocenica Sism. var. *hofmanni* NOZSKY, 1939, Ann. Mus. nat. Hungarici, **32**, pars Min. Geol. et Palaeont., pp. 43, 113, pl. 2, fig. 25.

Nozsky compared this "skulpturierter Steinkern" with *Lima (Acesta) postclypeiformis* Sacco and it resembles that species (as well as *inoceramoides* Sacco) in being ornamented by concentric undulations. The illustration suggests that the cast is badly broken and incomplete; but if a restoration be made on the basis of the trend of the undulations, it would seem that this form is even more broadly orbicular than *postclypeiformis*, and like the "variety" *marginatostriata* of Nozsky, would be more accurately referred to the *eocenica - postclypeiformis* sequence.

III. *PLICACESTA*, A NEW SUBGENUS OF *LIMA*

PLICACESTA H. E. Vokes, new subgenus

Type species, *Lima smithi* Sowerby 1888.

Typical forms of *Lima (Acesta)* are characterized by the possession of a posteriorly situated cardinal area with a markedly oblique ligamental pit, a very thin shell, and an ornamentation of weak, irregular radial ribs that are, essentially, inscribed on the surface of the valve by shallowly impressed grooves rather than by the more conventional type of interspaces. This radial ribbing is stronger toward the valve margins than on the central portion of its surface. The Recent species *Lima smithi* Sowerby, and certain fossil species in the Japanese Tertiary faunas, while possessing a cardinal area with a ligamental pit similar to that of *Acesta*, differ in the strong radial ribbing that plicates the relatively thin shell, rather than being exclusively a surficial feature, and is almost as strongly evident on the interior of the valve as it is on the exterior. Characteristically, also, the radial ornament is more strongly developed on the median portion of the valve than it is near the lateral margins.

LIMA (PLICACESTA) SMITHI Sowerby

Lima smithi SOWERBY, 1888, Zool. Soc. London, Proc. for 1888, p. 207, pl. 11, fig. 12.

Lima (Acesta) smithi Sowerby. THIELE, 1918, Conchylien-Cab., (N.F.) **7** (2a), Fam. Limidae, p. 21, pl. 4, figs. 1, 2; OYAMA, 1943, Conch. Asiatica, **1** (1), Fam. Limidae, p. 45, pl. 4, figs. 3a, b; pl. 14, fig. 11.

Acesta smithi (Sowerby), HABE, 1958, Seto. Mar. Biol. Lab., Publ. **6** (3), p. 270.

Lima smithi was originally described by Sowerby as "Resembling in form *L. excavata*, but very decidedly ribbed. The auricles, cardinal area, and anterior lunule are much the same as in . . . *L. goliath*, but that species is smooth, excepting at the side, and not so inflated."

Habe reports the species in the collections of the "Sôyô-maru" at depths ranging from 115 to 669 meters, and indicates the geographic range as "Honshu (south to Suruga Bay and Wakasa Bay)". Suruga Bay is located at 35° N. lat. on the eastern side of Honshu, and Wakasa Bay near 36° on the Japan Sea. *Lima smithi* has not been reported as a fossil so far as I have been able to determine from the literature.

LIMA (PLICACESTA) AMAXENSIS Yokoyama

Lima amaxensis YOKOYAMA, 1911, Coll. Sci., Univ. Tokyo, Jour., **27**, art. 20, p. 15, pl. 3, fig. 2; NAGAO, 1928, Tohoku Imp. Univ., Sci. Repts., (2) Geol., **9** (3), p. 104, pl. 20, fig. 35.

Lima (Acesta) amaxensis Yokoyama. OYAMA, 1943, Conch. Asiatica, **1** (1), Fam. Limidae, p. 43, pl. 5, fig. 1.

Lima amaxensis is very like *Lima smithi* in the pattern of its ornamentation. but differs in being wider in proportion to the height of the valve, and hence has a more orbicular appearance. It was described from the Itchôda (or Icchôda) Formation of the upper Eocene at the Miike coal field, Kumamoto Prefecture, Kyushu, Japan.

LIMA (PLICACESTA) SAMESHIMAI Oyama and Mizuno

Lima (Acesta) sameshimai OYAMA and MIZUNO, 1958, Geol. Survey Japan, Bull., **9** (9), p. 10, pl. 1, figs. 11, 12.

This species from the "Lower ?" Oligocene of central Honshu, Japan, has a relatively narrow and high shell that is somewhat more produced anteriorly than is *L. smithi*, and is particularly marked by the fact that the rounded radial ribs are separated by broad round-bottomed interspaces that are as wide as the ribs. Judging from the illustrations the ribbing tends to become almost obsolete toward the valve margins.

LIMA (PLICACESTA ?) PROTOSQUAMOSA Noetling

Lima protosquamosa NOETLING, 1901, Palaeont. Indica (n.s.), **1** (3), p. 114, pl. 3, figs. 10, 10a.

Lima (Acesta) protosquamosa Noetling. OYAMA, 1943, Conch. Asiatica, **1** (1), Fam. Limidae, p. 44, pl. 5, fig. 5; pl. 14, fig. 10.

This small species from Singu, Burma, has been referred by Oyama to *Lima (Acesta)*. The illustrations are not clear as to the nature of the ligamental area, and are equivocal as to whether the species is better referred to *Lima (Lima)* or to *L. (Plicacesta)*; it clearly is not an *Acesta*.

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CENOZOIC MURICIDAE OF THE WESTERN ATLANTIC REGION

PART I—MUREX *sensu stricto*

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CONTENTS

Page

I. ABSTRACT 95
II. INTRODUCTION 95
III. ACKNOWLEDGMENTS 96
IV. SYSTEMATIC DESCRIPTIONS 98
V. APPENDIX I: References for species cited 111
VI. APPENDIX II: Locality data 112
VII. LITERATURE CITED 113

TABLE I: Recent species of *Murex* s.s. in the western Atlantic, with depth ranges 96

TABLE II: Distribution of fossil species of *Murex* s.s. 97

ILLUSTRATIONS

PLATE I 117
PLATE II 119
PLATE III 121
PLATE IV 123

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CENOZOIC MURICIDAE OF THE WESTERN ATLANTIC REGION

PART I—MUREX *sensu stricto*

EMILY H. VOKES
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I. ABSTRACT

A study of the marine gastropods of the subgenus *Murex* sensu stricto (type *M. tribulus* Linné) shows that in the fossil record of the western Atlantic region there are 19 species-groups referable to this subgenus. From the same area 15 Recent species are known, only four of which occur in the paleontological record. The oldest species definitely referable to this group appear in the lower Miocene with ten species of this age reported from localities extending from Florida to Brazil. Two subgroups may be recognized, one here termed the "Western Atlantic" subgroup, the other the "Indo-Pacific" subgroup. Both subgroups are present in the western Atlantic today, with the "Indo-Pacific" group generally inhabiting water less than 50 fathoms in depth, and the "Western Atlantic" group in the cooler water of somewhat greater depths.

II. INTRODUCTION

The genus *Murex* was established in 1758 by Linnaeus (p. 746) and originally comprised all of the gastropods with:

> "Testa univalvis, spiralis, exasperata suturis membranaceis. Apertura desines in canalem integrum rectum s. subadscendentum." [Shell univalve, spiral, rough with membranaceous ridges. Aperture ending in a straight, or slightly ascending canal (translation from Dillwyn, 1817, p. 680).]

Linnaeus included a wide variety of shells which subsequently have been divided and redivided into nearly as many genera as the original 59 Linnaean species. Linnaeus himself divided the genus into six subgroups, of which only two are today included even in *Murex* sensu lato. The first of these, "*α*", was characterized as "Spinosi cauda exserta," and includes *M. tribulus,* selected by Montfort in 1810 (p. 619) as the type species of the genus.

Murex sensu stricto therefore consists of those species with an elongated siphonal canal and three varices, more or less spinose. This subgenus, however, may be further subdivided into two groups. The first might be termed the "Indo-Pacific" form, with a straight siphonal canal, showing little or no trace of former canals. Many species of this group, including *M. tribulus,* bear a series of varical spines down the length of the canal. The second, or "Western Atlantic" group, differs in that the siphonal canal is deflected to the left, and as the successive canals form, these ends remain as a series of divarications. This form is restricted to the western Atlantic today and many of the early fossil species were of this type. The "Indo-Pacific" form seems to have flourished farther south originally, but both groups now live over all of the area.

According to data collected by the "Challenger" and "Siboga" expeditions (Watson, 1885; Schepman, 1911), the approximately thirty known species of *Murex* s.s. in the Indo-Pacific region today live in water depths of less than 50 fathoms. Those members of the "Indo-Pacific" group which inhabit the western Atlantic are also shallow water forms (see Table I), while the members of the "Western Atlantic" group generally occur in deeper water. The "Indo-Pacific" species appear to be more successful; however this may be only a reflection of the fact that deeper water species are less easily collected. Deep-water dredgings made by the U. S. Fish and Wildlife M/V *Oregon* show that many of the species considered rare are not so, but occur in great numbers in the comparative obscurity of the depths (H. R. Bullis, Jr., personal communication). Originally the "Western Atlantic" group inhabited shallower water, the occurrence with such genera as *Conus, Arca, Strombus, Turritella, Macrocallista* and others indicates a water depth of less than 50 fathoms, but presumably rising temperatures in Recent times have caused the group to move into slightly deeper water.

Although the geologic history of the genus *Murex* begins in the Paleocene, *Murex* s.s. does not appear until somewhat later, possibly in the Oligocene. There are species in the upper Eocene of Australia which could be ancestral to the group, and the form prob-

ably developed in the Indo-Pacific area. In the western Atlantic region the first true *Murex* s.s. appear in the lower Miocene, though there are species of other subgenera back to the Paleocene. *Murex quirosensis* Hodson was described from the upper Oligocene of Venezuela, and if this age is correct it is the oldest *Murex* s.s. in this area. However, the age assignment is subject to some doubt (see remarks under that species), and it too is probably lower Miocene in age. *M. quirosensis* is closely related to forms in the Chipola Formation of northern Florida (uppermost lower Miocene), and is either ancestral to (if the age is correct), or contemporaneous with them. In the Chipola Formation there is suddenly an "explosion" of true *Murex* s.s., both in species and in number of individuals, but this may be only a facies phenomenon as the Chipola is a fine sand such as that preferred by living *Murex* s.s.

Coincident with the appearance of the "Western Atlantic" form to the north is that of the "Indo-Pacific" form to the south. Species in the Pirabas Limestone of Brazil, which has been correlated with the Chipola (Maury, 1925, p. 32), as well as *M. messorius* Sowerby of the Caribbean, are of this latter stock. *M. messorius* was a vigorous species which rapidly spread over most of the Caribbean area and still survives, virtually unchanged, today. *M. recurvirostris* Broderip, believed by some to be synonymous with *M. messorius,* is found today on the western coast of Central America from Ecuador to the Gulf of California. This species is closely related to *M. messorius* and doubtless shares a common ancestry. Another West Coast species, *M. elenensis* Dall, is similar to *M. recurvirostris,* though larger and with rows of varical spines down the canal, but is even more closely related to *M. cabritii* Bernardi from the Gulf of Mexico, a species unique among Atlantic Murices in having a spinose canal. Although the two undoubtedly have a common history, no American fossil exhibits this otherwise Indo-Pacific trait, and the ancestry of these two unusual species is unknown.

This study has revealed 19 species-groups referable to *Murex* s.s. in the fossil record of the western Atlantic region (see Table II). Ten of these species have been reported from the lower Miocene, five in the Chipola Formation of Florida and five in the equivalent Pirabas Limestone. Six species occur in middle Miocene beds, four in the upper Miocene, and six in the Pliocene and Pleistocene. In addition there are 15 species known only from the Recent.

An attempt has been made to include all pertinent references for the fossil species, but synonymies for those species which are extant do not, for the most part, include references to the Recent representatives, the latter having been covered by Clench and Pérez Farfante (1945 *et seq.*). All type and figured specimens originally from the Tulane Geological Collections have been deposited in the United States National Museum.

TABLE I
RECENT SPECIES OF *MUREX* S.S. IN THE WESTERN ATLANTIC, WITH DEPTH RANGES

"Indo-Pacific" form
M. cabritii Bernardi: 18-76 fathoms
M. chrysostomus Sowerby: no data
M. maculatus Verrill: 40-50 fms.*
M. messorius Sowerby: 40 fms.*
M. recurvirostris sallasi Rehder & Abbott: 18-50 fms.
M. rubidus Baker: 6-85 fms.
M. tryoni Hidalgo: 25-115 fms.
"Western Atlantic" form
M. aguayoi Clench & Pérez Farfante: 185-285 fms.
M. cailleti Petit: 54-200 fms.
M. cailleti kugleri Clench & Pérez Farfante: 25-180 fms.
M. ciboney Clench & Pérez Farfante: 60-248 fms.
M. finlayi Clench: 100 fms.*
M. antillarum Hinds: 40-100 fms.
M. motacillus Gmelin: 95 fms.*
M. pulcher A. Adams: 40-60 fms.

These figures are not definitive but are based on the scanty data available. The data are taken from Clench and Pérez Farfante (1945), Springer and Bullis (1956), unpublished dredging records, and original authors.

* Representing only one record.

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TABLE II
GEOLOGIC AND GEOGRAPHIC DISTRIBUTION OF FOSSIL SPECIES OF *MUREX* S.S.

	U. Oligocene	L. Miocene	M. Miocene	U. Miocene	Pliocene	Pleistocene	Recent	
M. quirosensis F. Hodson	?							?Agua Clara Fm., Zulia, Venezuela
M. chipolanus Dall		x						Chipola Fm., Florida
M. gardnerae E. H. Vokes, n. sp.		x						Chipola Fm., Florida
M. gilli (Maury)		x						Chipola Fm., Oak Grove Sand, Florida
M. gilli polynematicus Brown & Pilsbry			x					Gatun Fm., Panama
M. vaughani Maury		x						Chipola Fm., Florida
M. pennai Maury		x						Pirabas Limestone, Pará, Brazil
M. toreia Maury		x						Pirabas Limestone, Pará, Brazil
M. williamsi Maury		x						Pirabas Limestone, Pará, Brazil
M. sutilis White		x						Pirabas Limestone, Pará, Brazil
M. messorius Sowerby		x	x	x	x	x	x	Pirabas Limestone, Brazil; Quebradillas Limestone, Porto Rico; Gurabo and Cercado Fms., Santo Domingo; Agueguexquite Fm., Mexico; M. Miocene, Oriente, Cuba; Gatun Fm., Panama and Costa Rica; Bowden Fm., Jamaica; Punta Gavilan and Mare Fms., Venezuela; Recent, Caribbean
M. nicholsi Gardner	x	x						Chipola Fm., Shoal River Fm., Florida
M. domingensis Sowerby			x	x				Gurabo Fm., Santo Domingo; Punta Gavilan Fm., Venezuela
M. yaquensis Maury			x					Gurabo Fm., Santo Domingo
M. antillarum Hinds			x	x	x	x	x	Bowden Fm., Jamaica; Recent, western Atlantic
M. rubidus Baker				x	x	x	x	Unnamed upper Miocene formation, Caloosahatchee Fm., and unnamed post-Caloosahatchee formation, Florida; Recent, Florida and Bahamas
M. chrysostomus Sowerby					x	x	x	Mare Fm., Venezuela; Recent, western Atlantic
M. anniae M. Smith					x			Caloosahatchee Fm., Florida
M. anniae bellegladeensis E. H. Vokes, n. subsp.						x		Unnamed post-Caloosahatchee formation, Florida

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IV. Systematic Descriptions

Phylum Mollusca

Class Gastropoda

Subclass Prosobranchia

Order Neogastropoda (or Stenoglossa)

Suborder Rachiglossa

Superfamily Muricacea

Family Muricidae

Subfamily Muricinae

Genus Murex Linnaeus, 1758

Subgenus Murex s.s.

Murex (Murex) quirosensis F. Hodson
Plate 1, figures 4a, b

Murex recurvirostris quirosensis F. Hodson, 1931, Bull. Amer. Paleontology, v. 16, no. 59, p. 37, pl. 20, figs. 1, 2, 5 (*not* 3 as cited).

Diagnosis: "This subspecies differs from *M. recurvirostris* Broderip in being more slender, in having a more attenuate spire, in being more spinous especially in the younger stages, in having more delicate spiral sculpture, and in having 2 strong intervarical tubercules (sometimes a weak third one is present) instead of 3 or 4 commonly found in the recent specimens.

"Our Oligocene specimens have a thin, inconspicuous parietal callus which does not stand out from the parietal wall. In the lower Miocene, intergrading forms are found between this Oligocene form and those occurring in the Upper Tertiary, and usually show a strong parietal callus which stands out from the parietal wall.

"Age. Upper Oligocene.

"Holotype locality. Loc. 6, Quirós, District of Miranda, Zulia [Venezuela]; intergrading forms are found in the States of Zulia and Falcón. (*Sensu stricto*, also from the District of Buchivacoa, Falcón.)" (Hodson, 1931)

Shell small; spire elevated, suture deeply impressed. Protoconch smooth, conic, probably of three whorls (incomplete in holotype). Six post-nuclear whorls in adult. Spiral sculpture of alternating primary and secondary threads, with occasional tertiary threadlets intercalated; about 18 primaries on the body whorl and pillar. Axial sculpture of three stout varices bearing a single recurved spine at the shoulder of each, and two series of open spines on their anterior prolongation. Two intervarical ridges between each pair of varices. Aperture triangular in outline; labium appressed, indistinct except at anterior portion where four transverse rugae are developed. Outer lip bearing 12 denticles within the aperture, corresponding roughly to the primary spiral threads. Anterior canal long, straight, antecedent canals slightly divergent.

Dimensions of holotype: height 32 mm, greatest diameter, including terminal varix (excluding spines), 16 mm.

Holotype: PRI 24104.

Figured Specimen: PRI 24104 (holotype).

Discussion: Oil company "security regulations" prevented stratigraphic assignment for this locality which was given as "oil seep at El Mene de Saladillo, 1.5 km SW of Quirós" (corrected to Quiroz by Brann and Kent, 1960, p. 17). If the age is correct this would place the species in the Agua Clara Formation but the Oligocene in this area is now known to be much thinner than was previously believed and the assignment is therefore uncertain. No map differentiating the Oligocene from the Miocene is available, so for the time we accept Hodson's determination.

Regardless of age, this *Murex* is certainly a distinct species, and is allied more closely with *M. gardnerae* Vokes n. sp., from the Chipola Formation (lower Miocene) than with *M. recurvirostris*. If Oligocene, it is the earliest known Caribbean fossil definitely referable to *Murex* s.s.

Murex (Murex) chipolanus Dall
Plate 1, figures 3a, b

Murex chrysostoma Gray, var. *chipolana* Dall, 1890, Wagner Free Inst. Sci., Trans., v. 3, pt. 1, p. 139.

not *Murex* (*Murex*) *chipolanus* Dall. Gardner, 1947, U.S.G.S. Prof. Paper 142-H, p. 517, pl. 53, figs. 1, 2. (=*M. gardnerae*, n. sp.)

Diagnosis: "The specimens from the Chipola River differ from the recent *M. chrysostoma* in being smaller than the average adult recent specimens, with a slightly shorter canal, from which the antecedent canal tends to divaricate, while in the typical *chrysostoma* it is usually continuous.

"The anterior margin of the varices in the fossil also tends to be more spinose or to have the projecting points more produced

than in the recent shell, though similarly situated and similar in number." (Dall, 1890)

Shell of moderate size; protoconch smooth, conic, 3½ whorls. Post-nuclear whorls, six or seven; body whorl inflated. Spiral sculpture of irregularly alternating primary and secondary threads, with some tertiary threadlets; 12 to 14 primary threads on body whorl and pillar. Axial sculpture of three strong varices, with one or two pronounced intervarical nodes. Where certain of the primary spirals cross these varices spines are produced, one strong at the shoulder, another almost as strong at the periphery, and two or three smaller on the anterior portion of the varix; in addition, one or two spines on the pillar. Aperture oval; labium with a heavy callus, standing free from the body wall at the margin; three or four rugae on the anterior half. Outer lip crenulated, and bearing within about eight denticles. Anterior canal long, recurved, with antecedent canals remaining as distinct divarications.

Dimensions of lectotype: height 38 mm, greatest diameter, including terminal varix (exclusive of spines), 20 mm.

Lectotype: USNM 112156.

Type locality: USGS 2212, Ten Mile Creek, one mile west of Chipola River, Calhoun County, Florida.

Figured specimen: USNM 112156 (lectotype). Other occurrences: TU locality nos. 70, 196, 430?, 456, 546; USGS 2213.

Discussion: Dall described this species from the Chipola Formation (uppermost lower Miocene) without a figure. In 1947, Gardner figured a specimen which she termed the "lectotype." However, collections from the Chipola River area have disclosed that two superficially similar species occur there; one is that figured by Gardner as *"M. chipolanus"*, the other agrees more closely with Dall's description. Presumably the two were considered the same by Gardner. Gardner's selection of a "lectotype" was unnecessary as a type had been selected by Schuchert and Dall (1905, p. 420) with the USNM number 112156 and the type locality of "Ten Mile Creek, Chipola River" (USGS 2212). A specimen bearing these type and locality numbers is present in the National Museum collections. The specimen figured by Gardner, clearly of the other species, is indicated as being from locality 2213, which is on the Chipola River, "one mile below Bailey's Ferry".

The United States National Museum record of these specimens reveals that USNM 112156 was catalogued as one specimen, with Ten Mile Creek, Chipola River given as the locality. Another single specimen, USNM 112157, was catalogued as one specimen from Chipola River at Bailey's Ferry. These two specimens were catalogued on the same day and are the only two that can be found labelled in Dall's handwriting. All other specimens dating from Dall's time (lot nos. 114250, 114251) were catalogued later and without identification in the catalogue; they now carry the old labels, but with identification in Gardner's handwriting. Both lots (114250, 114251) labelled in Gardner's handwriting now contain more specimens than when originally catalogued so there is no hope of discovering whether USNM 371885 (her "lectotype") may have been removed from either of them. Thus there seems to be sufficient reason for questioning whether Gardner's figured "lectotype" was actually one of the specimens originally identified by Dall. Therefore, *M. chipolanus* is redescribed and figured here for the first time, and Gardner's "lectotype" is referred to a new species, *M. gardnerae,* described below.

Murex (Murex) gardnerae E. H. Vokes, n. sp.

Plate 1, figures 1a, b

Murex (*Murex*) *chipolanus* Dall. Gardner, 1947, U.S.G.S. Prof. Paper 142-H, p. 517, pl. 53, figs. 1, 2. (*not* of Dall)

Diagnosis: Shell rather small for the group. Spire elevated; body inflated, rounded abruptly at the base into the slender pillar. Whorls of adult conch six or seven, moderately convex. Protoconch small, smooth, elevated, including four volutions. Axial sculpture of three varices, spinose at the periphery of the later whorls and the body, the spines slender, sickle-shaped, laminar, one of the primary spiral threads forming the midrib; spines not developed behind the periphery; commonly secondary spines in front of the periphery at the intersection with the primary spiral threads, especially on the base of the body and the pillar; primary varices on the medial whorls standing up like heavy, well-rounded cords; two or three more or less irregular secondary axial ribs usually developed between each pair of primary ribs on the spire, on the body commonly reduced to peripheral tubercules; on the early whorls usually eight to ten equisized and equispaced, well-rounded axial ribs crossed by three or four rather prominent spiral cords. Spiral threads subequal and equispaced; posterior

primary spiral forming the axis of the prominent varical spines; three or four lirae intercalated between the posterior peripheral primary thread and the posterior suture with or without additional secondary threadlets; two to four threadlets also intercalated between the two peripheral spirals; ten primary threads in front of the periphery of the body, subequal and regularly spaced, the wider interspaces with one or two fine lirae; sculpture on the pillar less regular, about six primary threads with intercalated secondaries. Aperture broadly oval, feebly notched posteriorly. Outer lip angulated at the periphery, the margin finely crenate. Inner wall of aperture excavated at the base of the body; labium reflected, forming a heavy callus, with its thin, sharp margin discrete from the body wall; corrugations within the margin rather heavy on the posterior half. Anterior canal long and slightly flexed toward its extremity, the former canals slightly divergent. Final canal roofed over and almost closed by a thin laminar plate of the callus. (After Gardner, 1947)

Dimensions of holotype: height 37.8 mm, greatest diameter, including terminal varix (excluding spines), 16.6 mm.

Holotype: USNM 643750.

Type locality: TU 456, Ten Mile Creek, about ½ mile downstream from bridge of Florida Highway 73, (NW¼ Sec. 12, T1N, R10W), Calhoun County, Florida.

Figured specimen: USNM 643750 (holotype). Other occurrences: TU locality nos. 70, 196, 458, 546; USGS 2212, 2213?.

Discussion: This species may be distinguished from *M. chipolanus,* with which it occurs, by the presence of one strong spine at the shoulder only, and secondary open spinelets on the anterior portion of the varices, rather than the two strong spines with several smaller spines, typical of *M. chipolanus.* It may also be distinguished by the longer, straighter canal, and by the two or three weak axial ribs, in contrast to the much stronger intervarical nodes of *M. chipolanus.*

The specimen figured by Gardner as "*M. chipolanus*", which has been discussed above, is an extraordinarily large individual. Although one specimen of similar dimensions has been collected by the writer (TU locality 546), most are considerably smaller, usually less than 25 mm in height. *M. chipolanus,* which tends to be 30 mm or more in the adult, is generally the larger species. Gardner's specimen was cited as being from USGS locality 2213 (TU locality 457). However, the writer has found no trace of this species in large collections made at that locality, and only three specimens have been collected anywhere along the Chipola River (at TU locality 458), but *M. gardnerae* is fairly common along Ten Mile Creek, west of the Chipola River, in a slightly more silty facies. Because of these factors it was deemed advisable to select as the holotype of this new species a specimen other than Gardner's, of a more typical size and from an established locality.

MUREX (MUREX) GILLI (Maury)

Plate 2, figures 1-4

Murex mississippiensis Conrad. DALL, 1890, Wagner Free Inst. Sci., Trans., v. 3, pt. 1, p. 139 (in part); DALL, 1915, U. S. Natl. Mus., Bull. 90, p. 73 (in part).

Fusus gilli MAURY, 1910, Bull. Amer. Paleontology, v. 4, no. 21, p. 137, pl. 22, fig. 3.

Murex (Murex) gilli (Maury). GARDNER, 1947, U.S.G.S. Prof. Paper 142-H, p. 518.

Murex (Murex) dasus GARDNER, 1947, U.S.G.S. Prof. Paper 142-H, p. 518, pl. 53, fig. 4.

Diagnosis: "Shell with six convex whorls of which the first three are smooth and the remainder sculptured. Spiral sculpture of well-defined threads alternating in size. Longitudinal sculpture of rounded riblets (ten on the last whorl). Suture waved; pillar nearly straight; aperture and canal keyhole shaped. Length of shell 9; greatest diameter 4 mm.

"Named in honor of Professor Gill of Cornell University.

"Oak Grove, Florida." (Maury, 1910)

Shell rather small for the group, moderately heavy, stout fusiform. Whorls of conch six to seven, broadly convex, rapidly increasing in diameter. Body whorl inflated, abruptly constricted into the moderately long and slender pillar. Protoconch small, smooth, conic, coiled 3½ times. Axial sculpture on the earliest whorls of about eight sharply rounded, well-elevated costae, separated by narrower intercostals; reduced on the final whorls to three varices, with one to three irregular riblets or nodes in the intervarical spaces; later varices usually produced into short, sharp spines at the shoulder, a primary spiral thread forming the midrib of the spines; one or two series of varical spines also developed on the pillar. Spiral sculpture close, sharp, and regular; primary spiral threads on the early whorls usually four, increasing to about seven on the final whorl of the spire, and 20 on the body and the pillar; interprimary areas crowded with secondary and tertiary threadlets. Aperture rather large, oblique, broadly rounded behind, smoothly contracting into the linear anterior canal; posterior canal obscure. Labrum broad,

arcuate; the margin elevated and heavily denticulated, the denticles approximately 15, corresponding roughly to the spaces between the primary spiral threads. Labium smoothly excavated, heavily glazed, the wash thinning on the base of the body so that the spiral sculpture shows through. Pillar straight, reinforced, the margin of the wash standing apart from the wall of the pillar, corrugated within the margin by four to six rugose denticles. Anterior canal moderately long and straight with parallel proximate margins. (After Gardner, 1947)

Holotype: USNM 639075.

Type locality: Oak Grove (TU locality 91), Florida.

Figured specimens: Fig. 1, USNM 643754 (topotype—*M. gilli*); height 35 mm, greatest diameter, including terminal varix (excluding spines), 23.5 mm; locality TU 91. Fig. 2, USNM 643752; height 32 mm, diameter 17 mm, locality TU 70. Fig. 3, USNM 639075 (holotype—*M. gilli*); height 9 mm, diameter 4 mm. Fig. 4, USNM 643753; height 8 mm, diameter 4 mm; locality TU 70. Other occurrences: TU locality nos. 196, 456, 458, 546, 549.

Discussion: Examination of the holotype of *Fusus gilli* reveals that it is a juvenile specimen of the species later named *M. dasus* by Gardner. (Compare Plate 2, figures 3 and 4.) As the original description was of an immature specimen, Gardner's description of the adult form (*M. dasus*) is also given. Gardner did not report *M. dasus* from the Oak Grove Sand; however, at the type locality of that formation (TU locality 91) it is one of the more common gastropods in a predominantly pelecypod fauna. The Oak Grove is now thought perhaps to be only a facies of the Chipola Formation where *M. gilli* is also common.

Murex (Murex) gilli polynematicus Brown and Pilsbry

Plate 2, figure 5

Murex polynematicus Brown and Pilsbry, 1911, Acad. Nat. Sci. Phila., Proc., v. 63, p. 353, pl. 26, fig. 1.

Murex (*Murex?*) *polynematicus* Brown and Pilsbry. Woodring, 1959, U.S.G.S. Prof. Paper 306-B, p. 215, pl. 36, figs. 2, 3; pl. 37, figs. 6, 9.

Diagnosis: "This form differs from the recent *M. recurvirostris* and the Oligocene subspecies *domingensis* Gabb [*sic*] by having more numerous spiral threads in the interval of the major spirals—three or four in each interval. There are six varices on the last one and a half whorls, none on the earlier whorls. The varices are not very large, and not excavated behind. A shoulder spine is present on the last two varices only, and is short and conic. The three intervarical spaces on the last whorl bear three, two and one folds, respectively. These folds are shorter and higher than in *recurvirostris*. Diameter 38 mm; length unknown, the anterior canal being broken." (Brown and Pilsbry, 1911)

"Moderately large, strongly shouldered, moderately spinose. Protoconch consisting of three acutely tapering whorls. Early post-protoconch whorls not shouldered, sculptured with axial ribs and three spiral threads. First varix appearing on third or fourth sculptured whorl or delayed until about sixth. Varices moderately pinched, well ahead of corresponding varix on preceding whorl. At first two or three strong axial ribs, extending from suture to suture, between varices; later two and finally on body whorl generally one, swollen and extended on shoulder but not reaching suture. Spiral sculpture of late whorls consisting of closely spaced threads of different rank. All except earliest post-protoconch whorls also sculptured with faint irregular axial swellings and microscopic irregularly spaced axial threads. Varices bearing a short erect spine at shoulder and on body whorl a blunt projection or low spine below the shoulder. One or two slender spines present or absent on pillar on the two varices preceding terminal varix. Edge of outer lip scalloped; interior bearing elongate denticles well within aperture. Siphonal canal moderately long, narrow, slightly bent backward, tip broken. Basal part of inner lip bearing elongate denticles.

"Height (incomplete) 54.5 mm, diameter (including terminal varix and its broken shoulder spine) 33.7 mm." (Woodring, 1959)

Holotype: Acad. Nat. Sci. Phila. 1719.

Type locality: Gatun Locks excavation, Canal Zone.

Figured specimen: USNM 643759; height 40 mm, greatest diameter, including terminal varix, 21 mm; locality USGS 16909.

Discussion: M. polynematicus, from the Gatun Formation (middle Miocene) of Panama, was described originally from an imperfect specimen; therefore, the expanded description of Woodring (1959) is cited also. This species is much too similar to *M. gilli* to be distinguished as a separate species. Woodring (1959, p. 216) says, "*M. dasus* [= *gilli*] is almost indistinguishable from small specimens of *M. polynematicus,* except that *M. dasus* has stronger secondary

axial sculpture." This characteristic is quite variable in *M. gilli* and probably is not a valid distinction, but until the writer has seen more specimens of *M. polynematicus* the subspecific designation will be applied. The principal difference, which may be ecological, seems to be size; the average *M. polynematicus* is about 50 mm in height, and the average *M. gilli* is 35 mm or less. However, one incomplete specimen collected from the Chipola beds (TU locality 458) approaches *M. polynematicus* in size.

MUREX (MUREX?) VAUGHANI Maury

Plate 1, figures 2a, b

Murex vaughani MAURY, 1910, Bull. Amer. Paleontology, v. 4, no. 21, p. 143, pl. 23, fig. 6.

Murex (Murex) vaughani Maury. GARDNER, 1947, U.S.G.S. Prof. Paper 142-H, p. 519.

Diagnosis: "Shell small, pyriform, compact, resembling in shape young specimens of *M. messorious* Sowerby of the Pliocene and recent faunas. Whorls about six, the nuclear nearly smooth, the three later whorls bearing each seven varices. On the body whorl the varices are prominent, rounded, somewhat broader than the interspaces. The varices of the shell form nearly continuous, sinuous lines from near the apex to the base of the canal. Spiral sculpture of raised lines of which groups of two or three are much stronger and stand out prominently from among alternating feebler spirals. Outer lip with about ten strong internal lirae; aperture oval; canal not quite half the length of the shell. Length of the shell 22.5; greatest width 14 mm.

"Chipola marls, Bailey's Ferry, Florida.

"Named in honor of Mr. T. W. Vaughan of the United States Geological Survey." (Maury, 1910)

Figured specimen: PRI 3461 (holotype). Other occurrences: TU locality 548.

Discussion: This rare species from the Chipola Formation is somewhat dubiously assigned to this subgenus. It has seven varices, while appearing otherwise to be a *Murex* s.s., and seems closer to the Recent *M. tumulosus* Sowerby (in a miniature version), than to any American species, fossil or Recent. Gardner (1947, p. 519) said of this shell, "nothing quite like it has been found in the collections available for study." One incomplete specimen has been collected by the writer (TU locality 548) and this apparently is only the second known example.

MUREX (MUREX) PENNAI Maury *emend.* E. H. Vokes

Plate 4, figure 5

Murex pennae MAURY, 1925, Ser. Geol. Min. Brasil, Mon. 4, p. 141, pl. 6, fig. 4.

Diagnosis: "Shell with somewhat the form of *Murex messorius* but with a much higher spire, and varices without spines. Whorls eight, including the nuclear [whorls]. The spire is very high and the convex whorls are separated by a deeply impressed suture. The imprint of one side of the shell in the limestone shows two varices extending continuously up the spire from whorl to whorl, almost vertically. The third varix is not shown. The varices are low, rounded, with no trace of any spines. On each whorl there are between the varices four, narrow, low, longitudinal ribs. The spiral sculpture consists of very sharply defined spiral threads, almost uniform though finer threads are sometimes interpolated. Anterior canal very long, perfectly straight, and the varices extend almost its entire length as sharp ridges. Aperture not preserved. Length of shell 50 mm, greatest diameter 20 mm.

"This beautiful *Murex* is dedicated to Sr. Ferreira Penna, who in 1876, discovered this fossiliferous outcrop.

"Locality—Rio Pirabas. [State of Pará, Brazil]" (Maury, 1925)

Discussion: It is regrettable that the preservation of the fossils in the Pirabas Limestone (lower Miocene) is in the form of molds, for the original illustration is so poor that any positive statement concerning relationships is impossible. However, this species bears a strong resemblance to some specimens of *M. domingensis* Sowerby from the Caribbean (see Plate 2, fig. 7) and it is probable that the two are synonymous.

The name of this species has been emended to *M. pennai,* as it was named for a man. (Art. 31, Int. Code Zool, Nomen., 1961, p. 33)

MUREX (MUREX) TOREIA Maury

Plate 4, figure 6

Murex toreia MAURY, 1925, Serv. Geol. Min. Brasil, Mon. 4, p. 145, pl. 6, fig. 11.

Diagnosis: "Shell small, fusiform, with a high spire comprising about seven whorls. Three varices are shown in the mold. The entire surface is reticulated by the intersection of very delicate, closely-set, longitudinal ribs and nearly uniform, spiral threads. Length of shell 24 mm, greatest width 11 mm.

"This species is recognized by its high

spire, convexly rounded whorls, reticulate surface, and graceful, delicate form.

"Locality—Rio Pirabas. [State of Pará, Brazil]" (Maury, 1925)

Discussion: This *Murex* from the Pirabas Limestone of the uppermost lower Miocene of Brazil is notable for the lack of constriction of the lower part of the body whorl. On the basis of Maury's figure it seems closer to the Recent *M. pulcher* A. Adams* (cf. Clench and Pérez Farfante, 1945, pl. 12) than to any fossil and may be ancestral to that atypical species which lives off Brazil today.

MUREX (MUREX?) WILLIAMSI Maury

Plate 4, figure 7

Murex williamsi MAURY, 1925, Serv. Geol. Min. Brasil, Mon. 4, p. 141, pl. 6, fig. 8.

Diagnosis: "Shell ovately pyriform, with five volutions which bear low, rounded, inconspicuous varices, presumably three to a volution, but the imprint shows only a portion of the shell. The earlier whorls are sculptured with narrow, delicate, longitudinal ribs, numbering about sixteen on the penultimate whorl. On the last whorl the ribbing is feebler, and about four weak ribs lie between a pair of varices. The entire shell is spirally sculptured with threads of unequal thickness, and on the convex part of the last whorl narrow, flat bands alternate with the spirals. The transverse growth lines are most apparent in the intervals between the spirals. Anterior canal somewhat bent, characters of aperture not preserved. Length of shell 34 mm, greatest width 16 mm.

"This interesting *Murex* is dedicated to Dr. Horace Williams of the Geological Survey of Brazil.

"Locality—Rio Pirabas. [State of Pará, Brazil]" (Maury, 1925)

Discussion: This species was described from a fragmentary mold in the Pirabas Limestone (lower Miocene). From Maury's illustration it is impossible to determine the distinguishing features, and its relationships are wholly unknown.

MUREX (MUREX) SUTILIS White

Plate 4, figure 8

Murex sutilis WHITE, 1887, Mus. Nac. Rio de Janiero, Arch., v. 7, p. 137, pl. 11, fig. 11.

Diagnosis: "Shell rather small; body subglobose; spire about equal in height to the breadth of the body portion of the last volution, exclusive of the beak; principal varices three in number to each volution, strong, prominent, laterally reflexed, crenulated, and bearing a few slender spines upon their edges, which are arranged in three continuous rows from the apex to the base of the beak. The spaces between the rows of principal varices are each traversed by three or four distinct but slightly raised, secondary varices, and also by numerous revolving raised lines, which are continuous with the crenulations of the varices; beak long and slender, its length equal to more than two-thirds the full length of the shell from the apex to the point of the beak; aperture suboval, a little longer than wide.

"Length from the apex to the point of the beak, 38 millimeters; greatest transverse diameter, including two of the varices, 17 millimeters.

"This species is represented in the collections only by some fragments, and a natural mould of the greater part of a shell. These specimens, however, show the generic and specific characteristics in a somewhat satisfactory manner. Notwithstanding the great geologic age of this species, it is plainly a typical *Murex*." (White, 1887)

Discussion: This *Murex,* described from the Pirabas Limestone of Brazil, was thought by White to be of Cretaceous age, hence the reference to "the great geologic age." Maury (1925, p. 139) correlated this formation with the Chipola Formation, and placed *M. sutilis* in synonymy with *M. messorius,* stating that "a very careful comparison of the fragments and of the figure of the more perfect specimen described by Dr. White as *Murex sutilis* with shells of *Murex messorius* indicates that the Pirabas specimens are small shells of the latter species." This may well be the case. However, the figure published by White is sufficiently different to cause the writer to withhold judgment until personal comparison with White's material is possible.

MUREX (MUREX) MESSORIUS Sowerby

Plate 3, figures 6-8

Murex messorius SOWERBY, 1841, Conchological Illustrations, pl. 194, fig. 93; SOWERBY, 1841, Zool. Soc. London, Proc., pt. 8, p. 137; SOWERBY, 1879, Thesaurus Conchyliorum, IV, *Murex,* p. 5, pl. 381, fig. 20.

Murex recurvirostris Broderip. GABB, 1873, Amer. Phil. Soc., Trans., (N.S.) v. 15, pt. 1, p. 201. (*not* of Broderip)

Murex messorius Sowerby. BROWN and PILSBRY, 1911, Acad. Nat. Sci. Phila., Proc., v. 63, p. 353.

Murex messorius Sowerby. MAURY, 1917, Bull. Amer. Paleontology, v. 5, no. 29, p.

* See page 111.

265, pl. 42, figs. 1, 2; MAURY, 1920, New York Acad. Sci., Sci. Surv. Porto Rico and Virgin Islands, v. 3, pt. 1, p. 63; MAURY, 1925, Serv. Geol. Min. Brasil, Mon. 4, p. 137, pl. 6, fig. 5.

Murex messorius Sowerby. OLSSON, 1922, Bull. Amer. Paleontology, v. 9, no. 39, p. 303.

Murex (*Haustellum*) *messorius* Sowerby. TRECHMANN, 1933, Geol. Mag., v. 70, no. 823, p. 38, pl. 4, fig. 14.

Murex recurvirostris Broderip. RUTSCH, 1934, Schweizer. Palaeont. Gesell., Abh., v. 54, no. 3, p. 64, pl. 4, fig. 1; v. 55, no. 1, p. 136. (*not* of Broderip).

Murex (*Murex*) *woodringi* CLENCH and PÉREZ FARFANTE, 1945, Johnsonia, v. 1, no. 17, p. 9, pl. 4, figs. 1-3.

Murex woodringi Clench and Pérez Farfante. AGUAYO, 1948, Soc. Malac. "Carlos de la Torre", Rev., v. 6, no. 2, p. 63.

Murex (*Murex*) *recurvirostris recurvirostris* Broderip. WOODRING, 1959, U.S.G.S. Prof. Paper 306-B, p. 214, pl. 35, figs. 5, 8; pl. 36, figs. 11, 12. (*not* of Broderip)

Murex (*Murex*) *recurvirostris* Broderip. PERRILLIAT MONTOYA, 1960, Paleontología Mexicana, no. 8, p. 21, pl. 3, figs. 10, 11. (*not* of Broderip)

Murex (*Murex*) *recurvirostris recurvirostris* Broderip. WEISBORD, 1962, Bull. Amer. Paleontology, v. 42, no. 193, p. 278, pl. 26, figs. 3, 4. (*not* of Broderip)

Diagnosis: "Mur. testa clavata, subventricosa, fulvo-rubescente, griseo, rubro, fuscoque maculata; spira brevi; cauda elongata, recta, angusta, minime recurva; varicibus tribus, crassis, costatis, ante crenulatis, pone foveolatis, ad angulum posticum spina brevi recta, ad caudam spina falcata, subelongata, deinde una breviore, recta; interstitiis duobus ad tribus costis noduliferis; apertura ovali, postice subcanalifera; labio interno postice tumido, intus crenulato; labio externo denticulato, antice paululum extante; canali fere clauso. Long. 2.40; lat. ex. var. .90 poll. [height 61 mm, width, 23 mm] Hab. ---? Mus. Cuming, Stainforth.

"Distinguishable by the thickened varices, and the spine at the base of the caudal canal, shaped like a reaper's hook." (Sowerby, 1841)

"Shell medium in size, from 50 to 72 mm (2 to 2¾ inches) in length, rather solid and moderately spinose. Whorls eight or nine, strongly convex. Ground color cream to dark gray with a wide band of a darker shade at the shoulder of the whorls; sometimes there is another immediately below the middle and a third one at the base of the whorls. These are best viewed from within the aperture. Spire acute and extended. Suture irregular and deeply indented. Aperture oval to subcircular, polished and colored from oyster white to dark gray and occasionally stained with brown. Parietal lip reflected, adhering to the body whorl above and free below the midpoint. Below the margin and on the inner wall of this lip there are from three to nine flattened denticles and a single rounded denticle at the upper extremity. Outer lip erect and possessing a series of very strong and long denticles with their forward ends producing a prominent crenulated edge on the lip. Siphonal canal narrow and extended, its length being a little less than the total height of the whorls. It is straight except for the distal end which is moderately turned upwards. Axial sculpture consists of three varices which are moderately spinose. At the shoulder of the whorls on each varix there is generally a large open spine and at the base of the varix at the beginning of the siphonal canal there is a rather large recurved, spur-like spine. Remaining spines on the varices are open in front and scale-like. Intervarical ridges are two in number on the early whorls and increase to four or five on the later whorls, though they may be reduced on the last whorl to only two. Spiral sculpture consists of alternating large and fine ridges, the larger culminating in a spine on each varix. Nuclear whorls one and one-half to two, rounded, glass-like and pale brown in color. The next two whorls possess very prominent axial ridges and somewhat finer spiral threads. Operculum subcircular, unguiculate and possessing very fine concentric lines." (Clench and Pérez Farfante, 1945)

Figured specimens: Fig. 6, USNM 643761; height 45.5 mm, greatest diameter, including terminal varix, 30 mm; locality USGS 8516. Fig. 7, USNM 639037; height 55 mm, diameter 26 mm; locality, Recent, Colon, Panama. Fig. 8 (nucleus only figured), USNM 643766; height 14 mm, diameter 8 mm; locality USGS 16926. Other occurrences: see discussion.

Discussion: Murex messorius is placed by some authors in synonymy with the West Coast shell, *M. recurvirostris* Broderip. Although they are similar, the two forms are distinguishable and, because of the geographic separation, it is more useful to keep them apart than to unite them. *M. recurvirostris* may be distinguished from *M. messorius* by its much shorter spire and its varices which are deeply excavated behind. A Pacific shell, *M. recurvirostris lividus* Carpenter, from the vicinity of Mazatlán, Mexico, shows strong affiliation with *M. messorius* and could represent an intermediate form. *M. recurvirostris sallasi* Rehder and Abbott found in the Caribbean should be

allied with the Atlantic species as it is closer to *M. messorius* than to *M. recurvirostris.*

Recently, Axel A. Olsson established (personal communication) by comparison with Sowerby's type in the British Museum (Nat. Hist.), that *M. woodringi* Clench and Pérez Farfante is a synonym of *M. messorius.* It is of interest that Clench and Pérez Farfante in their description of *M. woodringi* (cited above) make reference to the "large spur-like spine" at the base of the siphonal canal, the spine which Sowerby likened to "a reaper's hook". It is surprising that the similarity was not noted by these authors; however, it is probable that they, like others, were led astray by the confusion of *M. messorius* with *M. recurvirostris.*

M. messorius has been reported from beds as old as the uppermost lower Miocene in Brazil (Maury, 1925) and Porto Rico (Maury, 1920), from the middle Miocene of Santo Domingo (Gabb, 1873, as *recurvirostris;* Maury, 1917), Cuba (Aguayo, 1948), Costa Rica (Olsson, 1922), Panama (Brown & Pilsbry, 1911; Woodring, 1959, as *recurvirostris*), Mexico (Perrilliat Montoya, 1960, as *recurvirostris*), and other areas in the Caribbean. In Venezuela it has been reported from the upper Miocene (Rutsch, 1934, as *recurvirostris*) and the Pliocene (Weisbord, 1962, as *recurvirostris*). Clench and Pérez Farfante (1945, p. 10) suggested that the "*M. recurvirostris*" of Woodring from the Bowden Formation of Jamaica (Woodring, 1928, p. 288) is also this species. Woodring's figured specimen (*ibid.,* pl. 17, figs. 7, 8) is referable to *M. antillarum* Hinds (see discussion of that species), but the Tulane collections reveal that both *M. messorius* and *M. antillarum* occur in the Bowden.

The Recent distribution of *M. messorius* is much the same as the fossil. It ranges over all of the Caribbean and the Gulf of Mexico, exclusive of Florida. Although the species has been reported from Pliocene and Recent localities in Florida, it does not occur there and the species reported usually is *M. rubidus. M. messorius* and *M. rubidus* are mutually exclusive, perhaps the the result of differing temperature requirements.

Murex (Murex) nicholsi Gardner
Plate 3, figures 3-5

Murex (Murex) nicholsi Gardner, 1947, U.S.G.S. Prof. Paper 142-H, p. 519, pl. 53, fig. 3.

Diagnosis: Shell rather small, though probably reaching dimensions greater than those of the type. Whorls six or seven in the adult, broadly convex, increasing rapidly in diameter. Body well rounded medially, abruptly constricted into the pillar. Whorls closely appressed, the sutures inconspicuous and sinuated by the axial ribs. Protoconch smooth, polished. Axial ribs on the earliest turns narrowly rounded, sharply elevated, equal and equispaced; three narrow, rounded varices developed on the medial portion of the shell; spinose only at the intersection with the primary spiral thread which outlines the periphery. Spiral sculpture rather sharp; three narrow, angular, primary threads on the early whorls, the posterior outlining the shoulder; a fourth introduced on the later whorls; two or three secondary lirations may be developed, one of them approximating the primaries; spiral sculpture on the body regular; six subequal and subequispaced primary threads on the medial portion and the base, a secondary threadlet intercalated midway between each pair; three less fine secondaries developed between the posterior primary and the suture line, the medial a little coarser than those on either side; pillar with six or seven secondaries, more widely spaced anteriorly. Aperture obliquely lobate, broadly rounded behind, obscurely sulcate posteriorly. Outer lip broadly arcuate; margin crenulated; inner surface of terminal varix dentate. Inner wall of aperture more strongly convex than the outer, heavily glazed, rugose along the pillar; inner margin of pillar sharply rounded. Anterior canal long and straight. (After Gardner, 1947)

Dimensions of holotype: height 25 mm, diameter including varices, 14.5 mm.

Holotype: USNM 371851.

Type locality: Five to six miles west-northwest of Mossyhead, Walton County, Florida.

Figured specimens: Fig. 3, LSU 3419; height 34 mm, greatest diameter, including terminal varix, 21.5 mm; locality LSU 962. Fig. 4, USNM 643751; height 28 mm, diameter 11.5 mm; locality TU 70. Fig. 5, (nucleus only figured) USNM 643767; height 20 mm, diameter 9 mm; locality TU 70. Other occurrences: TU locality nos. 69A, 458, 554; LSU 853.

Discussion: The original description of *M. nicholsi* was based on imperfect material. Better specimens available to the writer permit certain observations to be made. The species attains a larger size; Plate 3, figure 3, shows a specimen 34 mm in height, with an incomplete apex and canal. If complete it would approach 45 mm, comparable to

the larger species from the Miocene. It is also more spinose, especially in the younger stages (fig. 4), with a tendency toward open spines on the anterior portion of the varices, and on the pillar. *M. nicholsi* is extremely close to *M. domingensis* from the Gurabo Formation of Santo Domingo. Gardner (1947, p. 519) stated that *M. nicholsi* differs from that species in being "less slender, with a shorter, broader canal, more elevated axials and less prominent primary spirals." In view of the variability of *M. domingensis* these factors probably would not be sufficient to separate the two species. However, the protoconchs are very different with *M. nicholsi* having 3½ conic whorls and *M. domingensis* having 1½ bulbous whorls whose axis is eccentric to the rest of the shell.

Although *M. nicholsi* was described from the Shoal River Formation (middle Miocene) the writer has collected four specimens from the lower Miocene Chipola Formation, thus extending the range.

Murex (Murex) domingensis Sowerby

Plate 2, figures 6-9

Murex domingensis Sowerby, 1850, Geol. Soc. London, Quart. Jour., v. 6, p. 49, pl. 10, fig. 5.
Murex domingensis Sowerby. Gabb, 1873, Amer. Phil. Soc., Trans., (N.S.) v. 15, pt. 1, p. 201.
Murex domingensis Sowerby. Guppy, 1876, Geol. Soc. London, Quart. Jour. v. 32, p. 521.
Murex domingensis Sowerby. Maury, 1917, Bull. Amer. Palaentology, v. 5, no. 29, p. 265, pl. 42, figs. 3-6.
Murex domingensis Sowerby. Rutsch, 1934, Schweizer. Paleont. Gesell., Abh., v. 54, no. 3, p. 65, pl. 4, fig. 2; v. 55, no. 1, p. 136.
Murex domingensis Sowerby. Ramirez, 1949, Univ. Santo Domingo, Inst. Geog. Geol., Pub. 70, p. 29, pl. 6, fig. 4.
Murex (Murex) domingensis Sowerby. Pflug, 1961, Acta Humboldtiana, Ser. Geol. Palaeont., no. 1, p. 44, pl. 10, figs. 7-13.

Diagnosis: "Testa subovata, utrinque subacuminata, trifariam varicosa, anfractibus senis, longitudinaliter costellatis, spiraliter valide striatis; varicibus prominentibus, rotundatis, marginibus paucispinosus, spinis brevissimus; labio columellari antice ruglosa; canali breviuscula." (Sowerby, 1850)

Shell size average for the group. Spire elevated; inflation of whorls variable with resultant change in overall shape. Eight whorls in the adult; protoconch polished, bulbous, consisting of 1½ whorls, axis eccentric. Three narrow varices developed on the earliest post-nuclear whorls, a single spine produced at the shoulder; occasionally small open spinelets on the anterior portion of the varices at the intersection with the primary spiral threads. Between the varices three to five narrow sharp axial ridges. Radial sculpture of primary and secondary threads with some tertiary threadlets; about 16 primary threads on the body whorl and pillar. Aperture variable from almost circular to oval; outer lip crenulated by about ten denticles; labium appressed at posterior portion, standing free at anterior portion, bearing eight to ten rugae. Anterior canal long and almost straight.

Dimensions of lectotype: height 45 mm, diameter 27 mm.

Lectotype: British Museum (Nat. Hist.) 83948 (selected by Pflug, 1961).

Type Locality: Dominican Republic.

Figured specimens: Fig. 6, USNM 643764; height 37 mm, greatest diameter, including terminal varix, 19 mm; locality USGS 8516. Fig. 7, USNM 643765; height 42.7 mm, diameter 20 mm; locality USGS 8516. Fig. 8, USNM 643762; height 31.7 mm, diameter 19 mm; locality USGS 8528. Fig. 9 (nucleus only figured), USNM 643763; height incomplete, diameter 7 mm; locality USGS 8528. Other occurrences: see discussion.

Discussion: M. domingensis is a common shell in the middle Miocene Gurabo Formation of Santo Domingo (Dominican Republic). It is exceedingly variable and for this reason three different specimens have been figured to show the range of variation. It may be distinguished from *M. messorius* Sowerby, with which it occurs, by its finer ornamentation, by the presence of varices on the earliest post-nuclear whorls, and by its unusual protoconch. *M. domingensis* is closely related to *M. antillarum* Hinds and is undoubtedly ancestral to that species which has the same type of protoconch. It differs from *M. antillarum* in its lack of spines other than at the shoulder and in the relatively uniform spiral ribbing which is finer and less swollen at the intersection with the axial ribs. Some specimens do have small open spinelets on the anterior portion of the varices, in the manner of *M. antillarum.*

Although Woodring (1928, p. 289) stated that *M. domingensis* is found only in the Gurabo Formation, Rutsch (1934) figured a shell from the Punta Gavilan Formation

(upper Miocene) of Venezuela, which is certainly conspecific with a specimen figured by Maury (1917, pl. 42, fig. 6) from Santo Domingo. Maury identified her shell as "an extraordinarily large specimen, 74 x 42 mm, apparently referable to *M. domingensis.*" Adult specimens of *M. nicholsi* Gardner from northwestern Florida are remarkably similar to adults of *M. domingensis,* but are easily distinguished by the very different nuclei and early postnuclear whorls, indicating that the resemblance is one of convergence rather than close relationship.

Guppy has reported "*M. domingensis*" from Springvale, Trinidad (1911, p. 4), from Jamaica (1866a, p. 288) and from Cumana, Venezuela (1866b, p. 576). However, the Jamaican form is most certainly *M. antillarum* (see remarks under that species), and the others may be *M. messorius,* which Guppy considered only a Recent species. Referring to *M. domingensis,* he stated, "to my eyes its nearest kindred is *M. messorius,* a West-Indian recent species" (1876, p. 521).

Murex (Murex) yaquensis Maury

Murex antillarum Gabb, 1873, Amer. Phil. Soc., Trans., (N.S.), v. 15, pt. 1, p. 202, non *M. antillarum* Hinds, 1844.

Murex yaquensis Maury, 1917, Bull. Amer. Paleontology, v. 5, no. 29, p. 266, pl. 42, fig. 7, *nom. nov.* for *M. antillarum* Gabb *non* Hinds.

Murex yaquensis Maury. Pilsbry, 1922, Acad. Nat. Sci. Phila., Proc., v. 73, p. 353.

Diagnosis: "Shell broadly fusiform, whorls eight, rounded, varices three, small, having small, sharp spines variable in number; body whorl inflated, rounded in broadly to the suture, without any marked angle above, below tapering convexly to a nearly straight, short canal; spire elevated, about as long as the mouth, less the canal. Surface ornamented by numerous, more or less alternating, acute, revolving ribs, with concave outer spaces; crossing these are rather indistinct longitudinal ribs, four or five between each pair of varices. These ribs are better marked where they cross the revolving lines, than in the interspaces. Nuclear whorls polished, rounded, and without ornament. Aperture ovate, constricted in advance, canal about equal in length to that of the mouth proper. Inner lip expanded, showing transverse striations; outer lip more strongly striate internally. Length 1.15 in.; width .75 in.

"A rare shell whose rounded form, thinner structure, more delicate varices and sculpture, and smaller size will all serve to distinguish it from the two preceding [*M. domingensis* and *M. recurvirostris*]." (Gabb, 1873)

"As Gabb's name is pre-occupied by Hinds, the fossil requires a new name and *yaquensis* seems appropriate [Rio Yaque].

"This species intergrades with *M. domingensis.* I have specimens with the form of the latter and the ribbing of the former species. Our typical shell is a metatype of Gabb's *antillarum.*" (Maury, 1917)

Discussion: This *Murex* from the middle Miocene Gurabo Formation of Santo Domingo is probably only a form of *M. domingensis,* as Maury suggested. However, without the study of a series of specimens it is considered unwise to place them in synonymy, and the writer provisionally accepts *M. yaquensis* as a valid species.

Murex (Murex) antillarum Hinds

Plate 3, figures 1-2

Murex antillarum Hinds, 1844, Zool. Soc. London, Proc., pt. 11, p. 126.

Murex (Murex) recurvirostris Broderip. Woodring, 1928, Carnegie Inst. Washington, Pub. 385, p. 288, pl. 17, figs. 7, 8. (*not* of Broderip)

Murex (Murex) antillarum Hinds. Clench and Pérez Farfante, 1945, Johnsonia, v. 1, no. 17, p. 12, pl. 6.

Diagnosis: "Mur. testa subfusiformi, pallida, trivaricosa; anfractibus septenis rotundatis; varicibus tribus rotundatis, spiniferis, postice fornicatis; ad angulum anfractuum spina unica elongata, deinde quinque breviusculis; interstitiis, tri-, vel rarius, quadrifarium nodulose-costatis, lineis tranversis fuscis pencillatis; canali elongato, aperto, prope anfractum basalem subflexo, spinis duabus cavis gerente. Axis 18 lin. Hab. Tortola, West Indies. Mus. Cuming." (Hinds, 1844)

"Shell medium in size, from 50 to 100 mm (2 to 4 inches) in length, rather solid and very spinose. Whorls eight or nine, moderately convex. Color from cream to rusty or purplish brown with three rather indistinct bands of a darker shade on each whorl. Spire extended. Suture irregular and deeply indented. Aperture oblique and oval, porcellaneous white, sometimes with a purple tint. Parietal lip reflected and adherent to the body whorl. The upper portion completely attached, the lower part somewhat erect and standing free. Below the margin of the parietal lip there are two sets of small denticles; there are three or four denticles on the inner wall near the siphonal canal and generally two denticles at the upper portion near the union with

the outer lip. One, in this latter group, is situated close to the margin, the other fairly well within the aperture. The palatal, or outer lip, is rather thin, erect and crenulated. The crenulation opposite the shoulder spine is drawn out to form a small tooth-like process. Siphonal canal short to medium in length in young specimens. Adults have the siphonal canal greatly extended, moderately recurved upwards and tapering to a rather narrow extremity. Two previous stages of the siphonal canal remain as scale-like spines and are to be seen on the aperture side of the shell at the lower left of the aperture.

"There are three prominent equidistant varices on each whorl. These are more or less aligned with the varices on the whorls above. Each varix supports a series of rather long and pointed spines, the largest being produced at the shoulder of the whorl. Remaining spines more or less irregular as to size. There are two fairly strong spines immediately below each varix on the siphonal canal. All the spines are open on their forward or apertural side, though many may have the opening reduced to a mere slit. In between the varices there are two to four axial ridges, two and three on the early whorls and generally four on the last whorl. In between the last two varices formed, these axial ridges may be reduced to one large and generally one or two smaller ridges. Spiral sculpture consists of numerous cords. Six or seven of these are larger and terminate at the spines on the varices; the remaining cords are much smaller and terminate on each varix in between the base of the spines. In addition, there exist very fine axial growth lines which appear as fine threads in between the cords. Nuclear whorls one and one-half, smooth, rounded and brownish in color; the three following whorls sculptured with numerous equal axial ridges and revolving raised threads. Remaining whorls as described above." (Clench and Pérez Farfante, 1945)

Figured specimens: Fig. 2, USNM 643757; height 31 mm, greatest diameter, including terminal varix, 19 mm; locality, Bowden, Jamaica. Fig. 1, USNM 634487; height 49 mm, diameter 22 mm; locality, Recent, Jamaica (40 fms.).

Discussion: Woodring (1928) figured a *Murex* from the Bowden Formation of Jamaica (middle Miocene) which he identified as "*M. recurvirostris* Broderip". This shell certainly is not *M. recurvirostris,* nor is it *M. woodringi* (= *M. messorius*), as suggested by Clench and Pérez Farfante (1945, p. 9). This writer believes that the specimen figured is actually *M. antillarum* with the spines broken away. The factors influencing this decision are: 1) the type of protoconch, which in *M. antillarum* consists of 1½ bulbous whorls in the manner of *M. domingensis* (see Plate 2, figure 9), and 2) the nature of the siphonal canal, which in *M. recurvirostris* and *M. messorius* is straight with previous canal so fused as to be quite obscure; in Woodring's figure, and in specimens from Bowden, the canal is deflected, with the termini of the antecedent canals divaricate, as in *M. antillarum.* Rutsch (1934, p. 65) came to the same conclusion on the basis of the much higher spire of the Bowden shell. Woodring later (1959, p. 215) reaffirmed his earlier identification, stating that *M. antillarum* "is larger, more spinose, and has a longer bent siphonal canal" than the Jamaican fossil. Specimens clearly show that spines were originally present and have been broken in the vicissitudes of fossilization. Woodring himself stated that "all except the shortest spines are broken" on all of the Bowden specimens (1928, p. 289). Plate 3, figure 2 is a small Recent specimen from Jamaica, approximately the same size as the fossil, included for comparison.

MUREX (MUREX) RUBIDUS Baker
Plate 4, figures 3-4

Murex messorius Sowerby. DALL, 1889, "Blake Report," Harvard Mus. Comp. Zool., Bull., v. 18, no. 29, pt. 2, p. 196 (in part); DALL, 1890, Wagner Free Inst. Sci., Trans., v. 3, pt. 1, p. 139 (in part).

"*Murex messorius* var *rubidum* Dall". BAKER, 1891, Rochester Acad. Sci., Proc., p. 157 (*nom. nud.*); BAKER, 1897, St. Louis Acad. Sci., Trans., v. 7, no. 16, p. 377.

Murex (*Murex*) *recurvirostris rubidus* Baker. CLENCH and PÉREZ FARFANTE, 1945, Johnsonia, v. 1, no. 17, p. 6, pl. 3, figs. 1-7.

Murex (*Murex*) *recurvirostris rubidus* Baker. OLSSON and HARBISON, 1953, Acad. Nat. Sci. Phila., Mon. 8, p. 242, pl. 36, fig. 3.

Diagnosis: "The shell is small, solid, the body whorl large, convex, roundly triangular in section, with 3 strong, humped varices at each corner, the summit of each rounded and crossed by spiral threads, a few of which, such as those placed on the shoulder and on the canal, especially in the young, may be elevated into short spines. Intervarical space wide, usually with two small ribs or humps in the middle. Spirals consist of strong, evenly spaced cords between wide, concave intervals. Anterior canal is long, straight, and slender (end often broken off). nearly closed, the si-

phonal channel remaining open only as a narrow slit. The protoconch is small, turbinate, of about 1½ whorls, smooth, the nuclear stage ending at a prominent rib. The early nepionic sculpture is coarsely reticulate, formed by about 9 subequal ribs intersected by 3 or 4 spirals, but on the third whorl each third rib is enlarged to form the varices of the later turns. Aperture subcircular, its peristome continuous in the form of a narrow rim, the inner and outer lips denticulate within." (Olsson and Harbison, 1953)

Figured specimens: Fig. 4, USNM 643755; height 28.8 mm, greatest diameter, including terminal varix, 14.8 mm; locality TU 520. Fig. 3, USNM 643756; height 29.6 mm, diameter 16 mm; locality TU 519. Other occurrences: TU locality nos. 68, 79, 201, 202, 203, 519 (over 200 specimens), 523, 527, 529, 539, 540.

Discussion: M. rubidus, a common species in Florida since the beginning of the Pliocene, has had a long and complicated nomenclatorial history. In the past it has often been confused with *M. messorius* Sowerby, as a result of Dall's statement in the "Blake Report" (1889, p. 196) that "the specimens [of *M. messorius*] off Florida are reddish pink." He gave no indication that he considered these to be a separate variety. The following year he reported "*M. messorius*" fossil in the "Pliocene marls of the Caloosahatchee River and Alligator Creek, Fla." as well as in Costa Rica and Santo Domingo, and living "in the Antilles and on the western coast of Florida and the Keys" (1890, p. 139). It is assumed that Dall considered the two forms identical, for Clench and Pérez Farfante report that, "so far as our records indicate *M. recurvirostris rubidus* is limited to Florida and the Bahamas, and does not extend into the remaining islands of the West Indies" (1945, p. 9) while *M. messorius* occurs only to the south of Florida.

F. C. Baker, in a catalogue of the family Muricidae (1891) apparently first recognized that the Florida shell was different from *M. messorius* and accordingly cited "*M. messorius* var. *rubidum* Dall, Blake Gastropoda, 1889, Cedar Keys." Because Dall had not named a *rubidum,* this reference must be considered a nomen nudum. In 1897 Baker again made reference to the form, stating in his discussion of *M. messorius* that "Dr. W. H. Dall has characterized a variety *rubidum* from Cedar Keys, the shell being of a deep pink color." Since, as noted above, Dall had not in fact "characterized" *rubidum* this name must be attributed to Baker.

Clench and Pérez Farfante (1945), considering *M. messorius* to be a synonym of *M. recurvirostris,* changed the name to *M. recurvirostris* subspecies *rubidus.* Olsson and Harbison (1953) likewise kept the subspecific designation, while remarking "the Florida shell is sufficiently distinct to be separated either in a subspecific or specific sense." As the species was never fully described by Baker, the description of Olsson and Harbison is cited above. This writer believes *M. rubidus* is a valid species, bearing no more than a subgeneric relationship to *M. recurvirostris* or *M. messorius.*

This species has been successful since it first appeared in the uppermost Miocene (? lowermost Pliocene, TU locality 520) of southern Florida. It has maintained its identity and abundance until the present time and exhibits remarkably little variation. This is unusual in such a prolific species; however the color of Recent specimens varies from pink to orange or yellow, and even brown. The earliest form (Miocene?) may be distinguished by the varices which are somewhat more deeply excavated behind (Pl. 4, fig. 4), similar to *M. recurvirostris.* The degree of development of this trait gradually diminishes from the Pliocene to the Recent and is not sufficient basis for separation.

Murex (Murex) chrysostomus Sowerby

Plate 4, figures 9a, b

Murex chrysostoma "Gray" Sowerby, 1834, Conchological Illustrations, pl. 58, fig. 1.
Murex (Murex) chrysostoma Sowerby. Clench and Pérez Farfante, 1945, Johnsonia, v. 1, no. 17, p. 10, pl. 5, figs. 1. 2.
Murex (Murex) chrysostomus Sowerby. Weisbord, 1962, Bull. Amer. Paleontology, v. 42, no. 193, p. 282, pl. 25, figs. 17, 18.

Diagnosis: "Shell medium in size, from 55 to 70 mm (about 2 to 3 inches) in length and solid. Whorls convex, seven to eight. Ground color buff with occasional specimens having bands and the spiral threads brownish. The siphonal canal may be stained irregularly with brownish patches. Spire moderately extended. Suture indented and irregular. Aperture large, oval, highly polished and of a cream color. The lower half of the parietal lip erect and extended forward, remaining upper half adherent to the body whorl. There are three spots of

yellow, two about midway on the lip and the other at its superior margin. In addition, there are a series of parallel denticulations a little below the margin and a well-developed tooth at the upper end. Outer lip strongly denticulated within, the ends of the denticulations forming a crenulated edge. Siphonal canal moderately long and tapering, broader on the columellar side. Earlier siphonal canals are obscure and in most cases completely adherent to the new canal. Axial sculpture consisting of three pronounced varices on each whorl which are rounded and nodulose instead of spinous. After the varix is produced, it is carried forward for a short distance and with the denticulations, there is formed a crenulated edge. The animal then proceeds to grow forward from below, leaving behind this crenulated margin as a sculpture character on the outer surface of the whorls. In between the varices there may be one to three axial and nodulose ridges which possess a strong knob at the whorl shoulder. At the base of the siphonal canal there may be one to three spur-like spines. Spiral sculpture consists of numerous raised threads which are developed into narrow and keeled ridges on both the varices and the axial ridges. Periostracum probably absent. Operculum unguiculate, possessing rather fine concentric ridges." (Clench and Pérez Farfante, 1945).

Figured specimen: USNM 643760; height 47 mm, greatest diameter, including terminal varix, 29 mm; locality USGS 18253.

Discussion: *Murex chrysostomus* was originally figured by Sowerby in the "Conchological Illustrations" without description; only the name appears in the accompanying list of species. Sowerby credited this species to "Gray", but it was never described by that person, and Sowerby is the true author; however Gray is frequently cited in the older literature.

Weisbord reported *M. chrysostomus* from the Mare Formation (Pliocene) of northern Venezuela. The fossil appears to be identical with the Recent form.

Murex (Murex) anniae M. Smith

Plate 4, figures 2a, b

Murex anniae M. Smith, 1940. Nautilus, v. 54, no. 2, p. 44, pl. 2, fig. 1.
Murex (Murex) anniae? Smith. DuBar, 1958, Florida Geol. Surv., Bull. 40, p. 196, pl. 11, fig. 5.

Diagnosis: "Shell of moderate size. Nucleus of 1½ whorls, the portion following the first half rounded and prominent, very similar to *M. cabritii* nucleus. Anterior canal comparatively short, straight, tip not recurved. Edge of outer lip bearing inside a series of blunt inconspicuous and widely separated denticles; outer lip well denticulated with in addition about seven long low processes upon the adjacent inner wall. There are three varices upon each whorl together with secondary spineless intermediate ribs. Spiral threads of two sizes cover the surface and extend over the varices. Certain of the primary threads form spines on the varices, these spines of fairly uniform size and few in number adjacent to the anterior canal; early whorls of spire presenting a reticulated appearance. The holotype, in the writer's collection, measures: length 33 mm, breadth 20 mm. A fragment exhibiting the aperture agrees perfectly with the holotype. Named in honor of the writer's mother Annie Lum Smith.

"This remarkable little *Murex* may be the progenitor of *Murex cabritii* now living in the Gulf of Mexico. The nucleus is almost identical with that species. The abbreviated canal of *M. anniae*, fewer and shorter spines, separate it from the latter species. From *M.* [*re-*] *curvirostris* Sowerby [*sic*] it differs in the straighter canal and in possessing fewer and coarser spines upon the varices." (Smith, 1940)

Figured specimen: DuBar 906; height 37 mm, greatest diameter, including terminal varix (excluding spines), 17.7 mm; locality, DuBar A31. Other occurrences: TU locality no. 531.

Discussion: This rare Caloosahatchee fossil is more closely related to *M. tryoni* Hidalgo than to either *M. cabritii* or *M. recurvirostris.* It differs from *M. tryoni* principally in the nature of the intervarical nodes. *M. anniae* has two strong axial nodes, in contrast to the four or five weak ridges characteristic of *M. tryoni.* Other minor differences include the number of varical spines, and the presence of about eight denticles on the outer lip, well within the aperture.

Smith gave no locality other than "Florida" for his shell, but Clench and Pérez Farfante (1945, p. 6) cite "Ortona Locks, Pliocene", stating that this information was "given in letter". This writer has not found *M. anniae* at Ortona, but DuBar (1958) figured a specimen (refigured here) collected near there, from his Station A31, Ayers Landing Marl Member of the Caloosahatchee Formation. (*Not* Station A19, Fort Thompson Formation, erroneously cited, DuBar, p. 196. Correct data from DuBar, personal communication.) A few specimens have been

collected at Port Charlotte, Florida (TU locality 531) which agree with the type.

Murex (Murex) anniae bellegladeensis E. H. Vokes, n. subsp.

Plate 4, figures 1a, b

Diagnosis: Shell of moderate size. Spire not elevated, body whorl inflated. Protoconch smooth, bulbous, consisting of 1½ whorls; adult conch having six whorls, the first three with no varices, but instead eight or nine equal axial ridges. The last three whorls ornamented by three strong varices bearing short, stout spines at the intersection of the primary spiral threads; two to three swollen intervarical nodes between each pair of varices. One or two series of spines on the anterior prolongation of the varices. Spiral ornamentation consisting of regularly alternating primary and secondary threads, about 20 primaries on the body whorl and pillar. Aperture oval, labium smooth and standing almost entirely free of the body wall. Seven to eight denticles on the outer lip well within the aperture. Canal long, straight, with no trace of previous canals, almost entirely roofed over by a thin laminar plate.

Dimensions of holotype: height 40 mm, greatest diameter, including terminal varix (excluding spines), 20.5 mm.

Holotype: USNM 643758.

Type locality: TU 201, two miles south of Belle Glade, Palm Beach County, Florida.

Figured specimen: USNM 643758 (holotype).

Discussion: This new subspecies, found only at the type locality, differs from the typical *M. anniae* in having stronger varices and much coarser ornamentation. Although the spines are located in the same relative position they tend to be shorter in the subspecies. In the early whorls of *M. anniae* the combination of the axial ridges and the pronounced spiral threads gives a reticulate appearance. In *bellegladeensis* the axial ornamentation is much stronger than the spiral, and predominates over it. This subspecies is closely related to *M. recurvirostris sallasi* which lives off Yucatán today. The latter species is even less spinose than *bellegladeensis,* and has much weaker intervarical nodes, but otherwise they are quite similar.

M. anniae bellegladeensis occurs in a formation which is as yet unnamed, although it has been termed locally the "Glades" formation. It unconformably overlies the Caloosahatchee, and is probably lower Pleistocene in age.

Notes on Recent Species

Those Recent species of *Murex* s.s. which have no fossil representatives have not been treated systematically in this work as they have been covered adequately by Clench and Pérez Farfante in their monograph "The genus *Murex* in the Western Atlantic" (1945 *et seq.*). References to original descriptions may be found in Appendix I.

Special mention should be made of *M. beaui* Fischer and Bernardi, and of *M. branchi* Clench. These two species (if they are not in fact conspecific) were not included by this writer in Table I because of their ambiguous nature. Although placed by Clench and Pérez Farfante in *Murex* s.s., they more closely resemble certain Japanese species* which have been placed in the subgenus *Siratus* Jousseaume. They seem to have no American Tertiary ancestors and presumably are very late arrivals on the scene.

It should also be noted that the name *M. pulcher* A. Adams is pre-occupied by *M. pulcher* J. Sowerby, 1813 (and also by Defrance, 1827). The next available name is *M. consuela* Verrill which was originally described as a subspecies of *M. pulcher* but which clearly is conspecific with it. Although there are those who do not approve of publication in a mimeographed paper, it is sanctioned by the International Commission for Zoological Nomenclature, albeit in a back-handed fashion. (Recommendation 8A states "Zoologists are strongly urged not to use mimeographing . . .", Intl. Code Zool. Nomen., 1961, p. 7.) Therefore we must accept *M. consuela* as the valid name for *M. pulcher* A. Adams, corrected here to *M. consuelae, emend.* E. H. Vokes.

V. Appendix I

REFERENCES FOR SPECIES CITED BUT NOT TREATED IN SYSTEMATIC DESCRIPTIONS.

M. aguayoi Clench & Pérez Farfante, 1945, Johnsonia, v. 1, no. 17, p. 15, pl. 8, figs. 1-3.

M. beaui Fischer & Bernardi, 1857, Jour. de Conchyl., v. 5, p. 295, pl. 8, fig. 1.

M. branchi Clench, 1953, Johnsonia, v. 2, no. 32, p. 360, pl. 179.

M. cabritii Bernardi, 1858, Jour. de Conchyl., v. 7, p. 301, pl. 10, fig. 3.

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* *M. pliciferoides* (Kuroda), *M. superbus* Sowerby, *M. propinqus* Kuroda and Azuma, and perhaps others.

M. cailleti Petit, 1856, Jour. de Conchyl., v. 5, p. 87, pl. 2, figs. 1, 2.
M. cailleti var. *kugleri* Clench & Pérez Farfante, 1945, Johnsonia, v. 1, no 17, p. 19, pl. 9, figs. 1, 2. New name for *M. similis* Sowerby, 1841, *non M. similis* Schroeter, 1805.
M. ciboney Clench & Pérez Farfante, 1945, Johnsonia, v. 1, no. 17, p. 20, pl. 10, figs. 1-3.
M. elenensis Dall, 1909, U. S. Natl. Mus., Proc., v. 37, p. 218. New name for *M. plicatus* Sowerby, 1834, *non M. plicatus* Gmelin, 1791.
M. finlayi Clench, 1955, Harvard Mus. Comp. Zool., Breviora, no. 44, p. 1, text figs. 1-3.
M. maculatus Verrill, 1950, Nautilus, v. 63, no. 4, p. 126, pl. 9, fig. 3. (*non M. maculatus* Reeve, 1845; probably synonymous with *M. cabritii*.)
M. motacillus Gmelin, 1791, Systema Naturae, ed. 13, v. 1, pt. 6, p. 3530.
M. propinquus Kuroda & Azuma, 1961, Venus, v. 21, no. 3, p. 30, text figure 3.
M. pulcher A. Adams, 1853, Zool. Soc. London, Proc., pt. 19, p. 270.
M. pulcher Defrance, 1827, Dict. Sci. Nat., v. 45, p. 547.
M. pulcher J. Sowerby, 1813, Mineral Conchology of Great Britain, v. 1, p. 63.
M. pulcher consuela Verrill, 1950, Conch. Club So. Calif., Mins., no. 101, p. 7, text figure.
M. recurvirostris Broderip, 1833, Zool. Soc. London, Proc., pt. 2, p. 174.
M. recurvirostris lividus Carpenter, 1857, Cat. Reigen Coll. Mazatlán Mollusca, p. 517.
M. recurvirostris sallasi Rehder & Abbott, 1951, Soc. Malac. "Carlos de la Torre", Rev., v. 8, no. 2, p. 58, pl. 9, figs. 7, 8.
M. superbus Sowerby, 1889, Zool. Soc. London, Proc. for 1888, p. 565, pl. 28, figs. 10, 11.
M. tribulus Linnaeus, 1758, Systema Naturae, ed. 10, v. 1, p. 746.
M. tryoni Hidalgo *in* Tryon, 1880, Manual of Conchology, v. 2, p. 134, pl. 70, fig. 427.
M. tumulosus Sowerby, 1841, Conchological Illustrations, pl. 189, fig. 71; Zool. Soc. London, Proc., pt. 8, p. 144.

VI. Appendix II

LOCALITY DATA

The following are Tulane University locality numbers:

68. Caloosachatchee Fm., North St. Petersburg, 70th Ave. at 9th St. N., Pinellas Co., Florida.
69A. Shoal River Fm., first ravine upstream from Shell Bluff, Shoal River (NW¼ Sec. 4, T3N R21W), about 3½ miles north of Mossyhead, Walton Co., Florida.
70. Chipola Fm., Ten Mile Creek, at bridge of Florida Highway 73 (NW¼ Sec. 12, T1N, R10W), Calhoun Co., Florida.
79. Caloosahatchee Fm., Ortona Locks, Caloosahatchee River, Glades Co., Florida.
91. Oak Grove Sand, type locality, west bank of Yellow River, about 100 yards below bridge at Oak Grove, Okaloosa Co., Florida.
196. Chipola Fm., Ten Mile Creek, about ½ mile upstream from bridge of Florida Highway 73 (NE¼ Sec. 11, T1N, R10W), Calhoun Co., Florida.
201. Unnamed post-Caloosahatchee formation, spoil banks, two miles south of Belle Glade, Palm Beach Co., Florida.
202. Caloosahatchee Fm., south bank of Caloosahatchee River, about two miles west of La Belle, Hendry Co., Florida.
203. Caloosahatchee Fm., north bank of Caloosahatchee River, about two miles east of Fort Denaud, Hendry Co., Florida.
430. Guajalote Fm., north bank of Rio San Fernando, at bridge of Mexico Highway 101, San Fernando, Tamalipas, Mexico.
456. Chipola Fm., Ten Mile Creek, about ½ mile downstream from bridge of Florida Highway 73, (NW¼ Sec. 12, T1N, R10W), Calhoun Co., Florida.
457. Chipola Fm., west bank of Chipola River (SW¼ Sec. 17, T1N, R9W), Calhoun Co., Florida. (same as USGS 2213)
458. Chipola Fm., east bank of Chipola River, just above Farley Creek, (Center Sec. 20, T1N, R9W), Calhoun Co., Florida.
519. Caloosahatchee Fm., Harney Pond Canal spoil banks, northwest side of Lake Okeechobee, Glades Co., Florida.
520. Unnamed formation, spoil banks, canal 1/3 mile east of Brighton, Highlands Co., Florida.
523. Caloosahatchee Fm., Harney Pond Canal spoil banks, 6 miles north of Florida Highway 78, Brighton Indian Reservation, Glades Co., Florida.
527. Caloosahatchee Fm., Pumping station 127, north shore Lake Okeechobee, Glades Co., Florida.
529. Caloosahatchee Fm., north bank of Caloosahatchee River, about three miles west of La Belle, Hendry Co., Florida.
531. Caloosahatchee Fm., Port Charlotte Development, spoil banks one mile west of Murdock railroad station on Florida Highway 771 (Sec. 12, T40S, R21E), Charlotte Co., Florida.
539. Caloosahatchee Fm., Shell Creek (Dall's locality), lower beds. About eight miles east of Cleveland, Charlotte Co., Florida.
540. Caloosahatchee Fm., Miami Canal spoil banks, one to three miles south of Palm Beach county line, Broward Co., Florida.
546. Chipola Fm., Ten Mile Creek, about 1½ miles west of Chipola River (NE¼

Sec. 12, T1N, R10W), Calhoun Co., Florida. (?same as USGS 2212)
548. Chipola Fm., west bank of Chipola River (NW¼ Sec. 29, T1N, R9W), Calhoun Co., Florida.
549. Chipola Fm., east bank of Chipola River, about ¼ mile below Four Mile Creek (NE¼ Sec. 32, T1N, R9W), Calhoun Co., Florida.
554. Chipola Fm., east bank of Chipola River (NW¼ Sec. 20, T1N, R9W), Calhoun Co., Florida.

The following are Louisiana State University locality numbers:

853. Shoal River Fm., Whites Creek (SW¼ Sec. 23, T2N, R18W), about eight miles southeast of DeFuniak Springs, Walton Co., Florida.
962. Shoal River Fm., southeast of bridge over Adams Mill Creek, a tributary of Shoal River (NW¼ Sec. 11, T3N, R21W), about three miles north of Mossyhead, Walton Co., Florida.

The following are United States Geological Survey locality numbers:

2212. Chipola Fm., Ten Mile Creek, one mile west of Bailey's Ferry* on Chipola River, Calhoun Co., Florida.
2213. Chipola Fm., one mile below Bailey's Ferry* on the Chipola River, Calhoun Co., Florida.
8516. Gurabo Fm., bluff on right bank Rio Amina at ford near Potrero, Province of Santiago, Dominican Republic.
8528. Gurabo Fm. Long bluff on left side Rio Mao about 3.5 kilometers below Cercado de Mao, Province of Santiago, Dominican Republic.
16909. Gatun Fm., Transisthmus Highway, 2.1 miles east of entrance to Coco Solo Naval Hospital, Canal Zone.
16926. Gatun Fm., South of Fort Davis, Canal Zone.
18253. Mare Fm., Cabo Blanco area, Distrito Federal, Venezuela.

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PLATES I-IV

Explanation of symbols

USNM—United States National Museum
USGS—United States Geological Survey
TU—Tulane University
LSU—Louisiana State University.
PRI—Paleontological Research Institution

Plate I

Page

1a, 1b. *Murex gardnerae* E. H. Vokes, n. sp. (X2) 99

USNM 643750 (holotype); height 37.8 mm, diameter 16.6 mm.
Locality TU 456. Chipola Fm., lower Miocene.

2a, 2b. *Murex vaughani* Maury (Fig. 2a, X2½; fig. 2b, X2) 102

PRI 3461 (holotype); height 22.5 mm, diameter 14 mm.
Locality, Chipola River. Chipola Fm., lower Miocene.
Photographs courtesy of Paleontological Research Institution.

3a, 3b. *Murex chipolanus* Dall (X2) 98

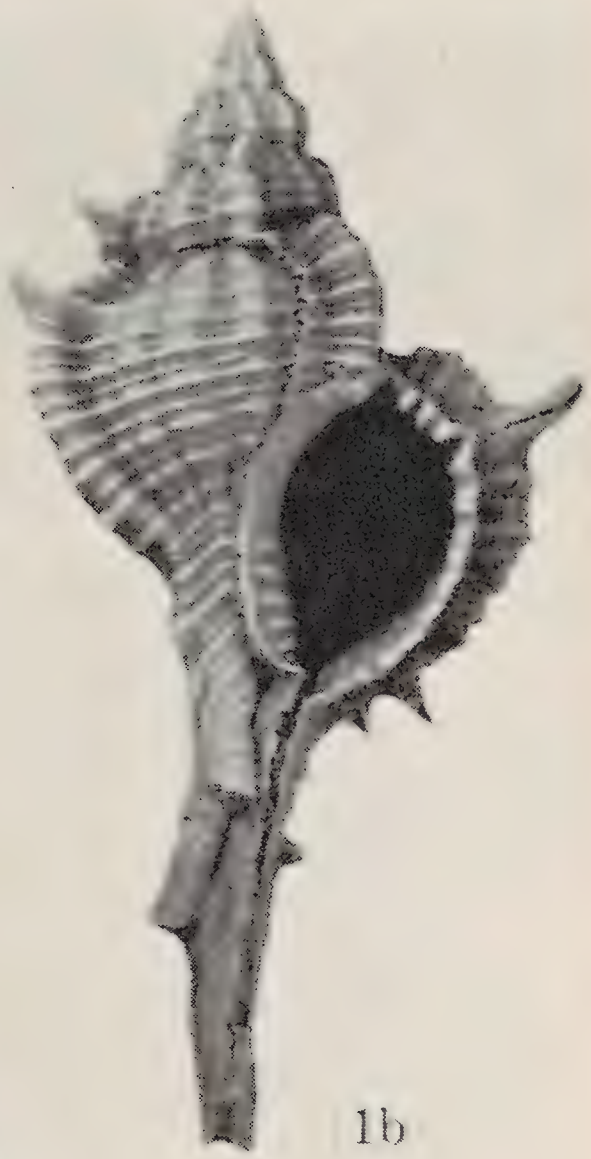
USNM 112156 (lectotype); height 38 mm, diameter 20 mm.
Locality USGS 2212. Chipola Fm., lower Miocene.

4a, 4b. *Murex quirosensis* F. Hodson (X2) 98

PRI 24104 (holotype); height 32 mm, diameter 16 mm.
Locality, Quiroz, Venezuela. ?Agua Clara Fm., upper Oligocene.

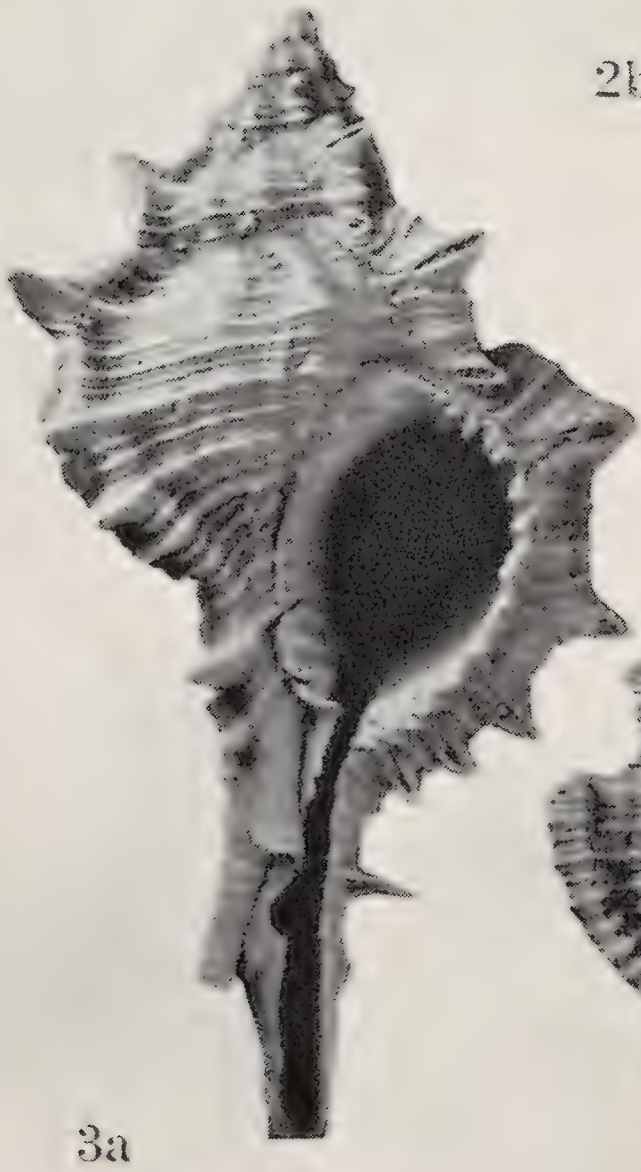
1a

2a



1b

2b



3a

3b

4a

4b

PLATE I

Plate II

Page

1-4. *Murex gilli* (Maury) ---------- 100

1. (X2) USNM 643754 (topotype); height 35 mm, diameter 23.5 mm.
Locality TU 91. Oak Grove Sand, lower Miocene.

2. (X2) USNM 643752; height 32 mm, diameter 17 mm.
Locality TU 70. Chipola Fm., lower Miocene.

3. (X4) USNM 639075 (holotype-*M. gilli*); height 9 mm, diameter 4 mm.
Locality, Oak Grove, Florida. Oak Grove Sand, lower Miocene.

4. (X4) USNM 643753; height 8 mm, diameter 4 mm.
Locality TU 70. Chipola Fm., lower Miocene.

5. *Murex gilli polynematicus* Brown & Pilsbry (X2) ---------- 101

USNM 643759; height 40 mm, diameter 21 mm.
Locality USGS 16909. Gatun Fm., middle Miocene.

6-9. *Murex domingensis* Sowerby ---------- 106

6a, 6b. (X2) USNM 643764; height 37 mm, diameter 19 mm.
Locality USGS 8516. Gurabo Fm., middle Miocene.

7. (X2) USNM 643765; height 42.7 mm, diameter 20 mm.
Locality USGS 8516. Gurabo Fm., middle Miocene

8. (X2) USNM 643762; height 31.7 mm, diameter 19 mm.
Locality USGS 8528. Gurabo Fm., middle Miocene.

9. (X10) USNM 643763; height incomplete, diameter 7 mm.
Locality USGS 8528. Gurabo Fm., middle Miocene.

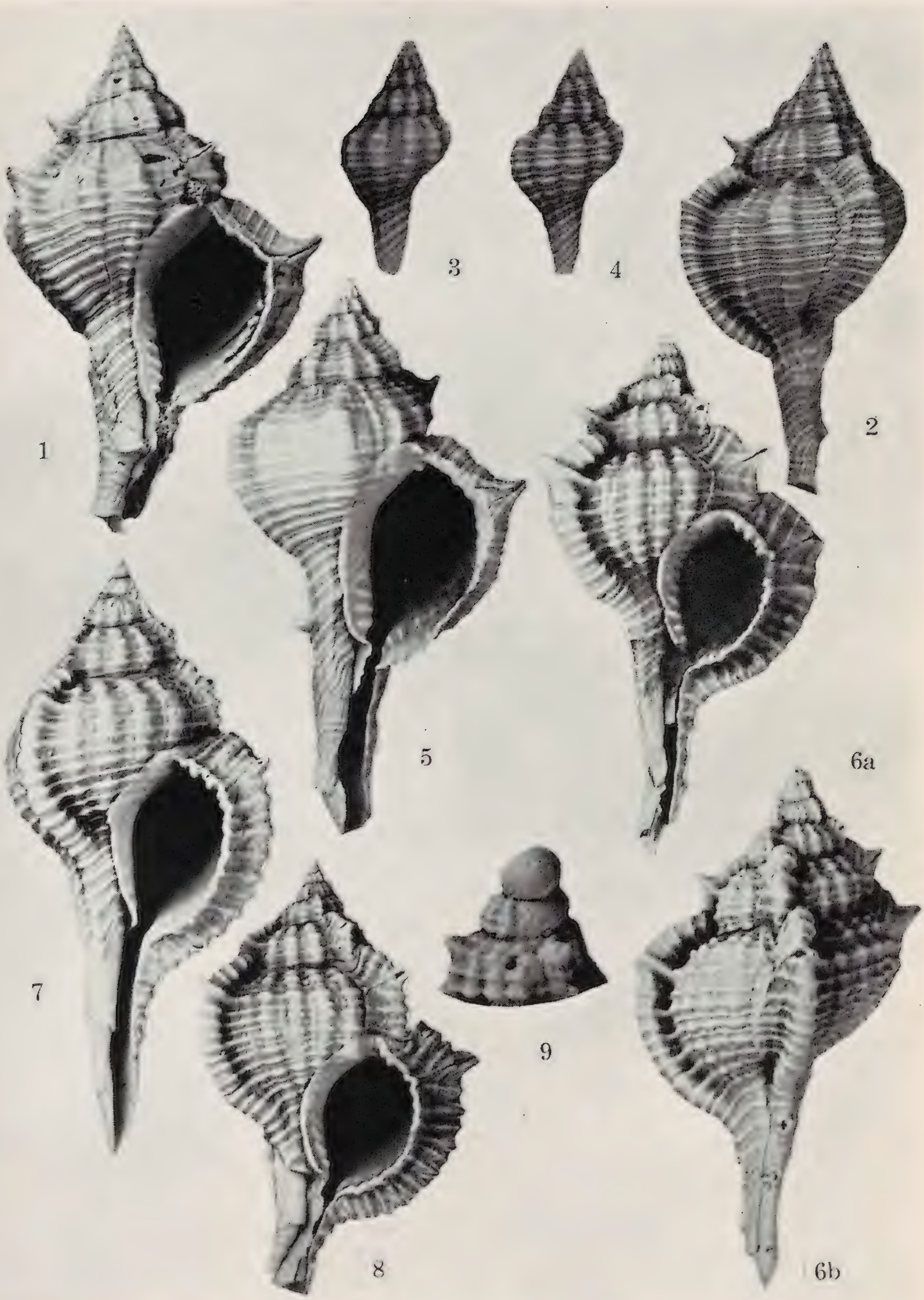


PLATE II

Plate III

Page

1-2. *Murex antillarum* Hinds 107

1. (X2) USNM 634487; height 49 mm, diameter 22 mm.
Locality, Jamaica (40 fms.). Recent.

2a, 2b. (X2) USNM 643757; height 31 mm, diameter 19 mm.
Locality, Bowden, Jamaica. Bowden Fm., middle Miocene.

3-5. *Murex nicholsi* Gardner 105

3. (X2) LSU 3419; height 34 mm, diameter 21.5 mm.
Locality LSU 962. Shoal River Fm., middle Miocene.

4. (X2) USNM 643751; height 28 mm, diameter 11.5 mm.
Locality TU 70. Chipola Fm., lower Miocene.

5. (X10) USNM 643767; height 20 mm, diameter 9 mm.
Locality TU 70. Chipola Fm., lower Miocene.

6-8. *Murex messorius* Sowerby 103

6a, 6b. (X1) USNM 643761; height 45.5 mm, diameter 30 mm.
Locality USGS 8516. Gurabo Fm., middle Miocene.

7a, 7b. (X1) USNM 639037; height 55 mm, diameter 26 mm.
Locality, Colon, Panama. Recent.

8. (X10) USNM 643766; height 14 mm, diameter 8 mm.
Locality USGS 16926. Gatun Fm., middle Miocene

PLATE III

Plate IV

Page

1a, 1b. *Murex anniae bellegladeensis* E. H. Vokes, n. subsp. (X2) 111

USNM 643758 (holotype); height 40 mm, diameter, 20.5 mm.
Locality TU 201. Post-Caloosahatchee formation, Pleistocene.

2a, 2b. *Murex anniae* M. Smith (X2) 110

DuBar 906; height 37 mm, diameter 17.7 mm.
Locality DuBar A31. Caloosahatchee Fm., Pliocene.

3-4. *Murex rubidus* Baker 108

3a, 3b. (X2) USNM 643756; height 29.6 mm, diameter 16 mm.
Locality TU 519. Caloosahatchee Fm., Pliocene.

4. (X2) USNM 643755; height 28.8 mm, diameter 14.8 mm.
Locality TU 520. Unnamed formation, ?upper Miocene.

5. *Murex pennai* Maury (XI) 102

From Maury, 1925.

6. *Murex toreia* Maury (X1) 102

From Maury, 1925.

7. *Murex williamsi* Maury (X1) 103

From Maury, 1925.

8. *Murex sutilis* White (X1) 103

From Maury, 1925.

9a, 9b. *Murex chrysostomus* Sowerby (X1) 109

USNM 643760; height 47 mm, diameter 29 mm.
Locality USGS 18253. Cabo Blanco Group, Pliocene.

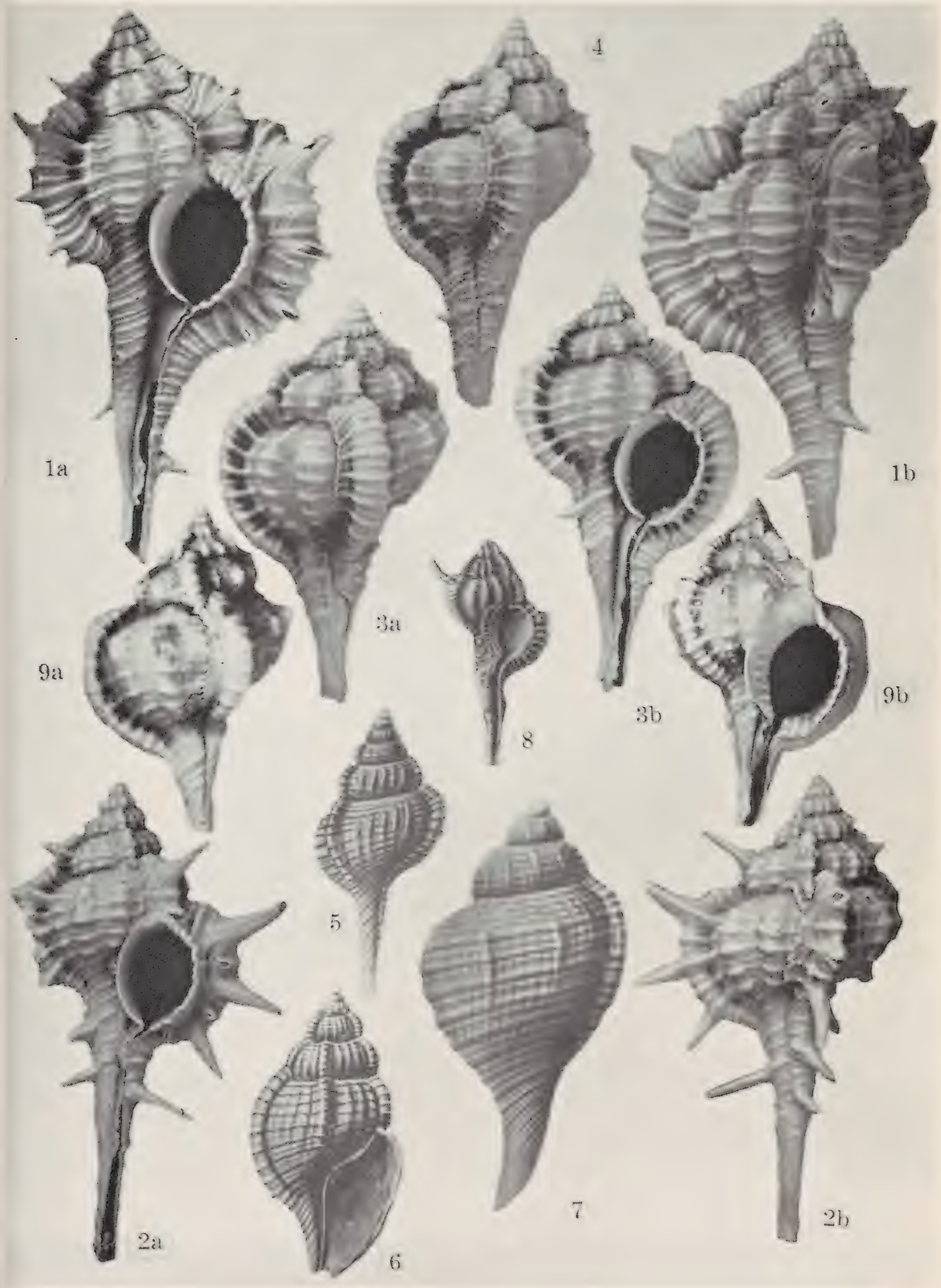


PLATE IV

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TULANE STUDIES IN GEOLOGY

Volume 1, Number 4 August 22, 1963

CONTENTS

GEOLOGY OF THE CAÑON DE LA HUASTECA AREA IN THE SIERRA MADRE ORIENTAL, NUEVO LEON, MEXICO

HAROLD E. VOKES

PROFESSOR OF GEOLOGY
TULANE UNIVERSITY

Page

I. Abstract 127
II. Introduction 128
III. Acknowledgments 128
IV. Stratigraphy 129
V. Structural Features 145
VI. Literature Cited 147
Plate 1: Cañon de la Huasteca 126
Plate 2: Geologic map of the Cañon de la Huasteca area ..... opposite page 130

A NEW SPECIES OF FORAMINIFERIDA FROM THE MIOCENE OF SOUTH LOUISIANA

HUBERT C. SKINNER

PROFESSOR OF GEOLOGY
TULANE UNIVERSITY

Abstract 149
Systematic Description 149

NOTES ON CENOZOIC MURICIDAE FROM THE WESTERN ATLANTIC REGION, WITH DESCRIPTIONS OF NEW TAXA

EMILY H. VOKES

TULANE UNIVERSITY

I. Abstract 151
II. Introduction 151
III. Systematic Descriptions 151
IV. Locality Data 163
V. Literature Cited 163
Plate 1 153
Plate 2 159

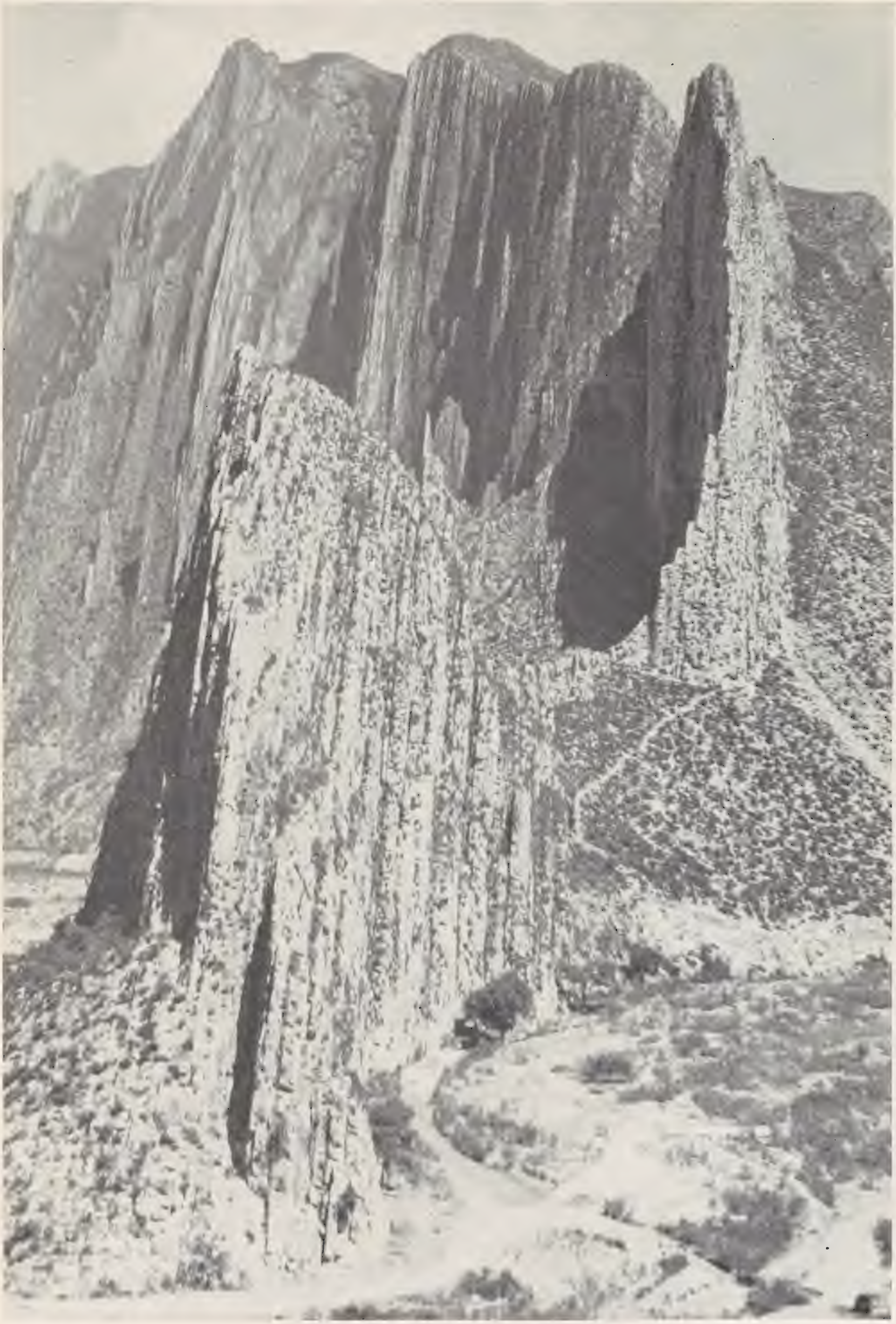

PLATE I: Vertical beds, Cañon de la Huasteca

GEOLOGY OF THE CAÑON DE LA HUASTECA AREA IN THE SIERRA MADRE ORIENTAL, NUEVO LEON, MEXICO

HAROLD E. VOKES

PROFESSOR OF GEOLOGY
TULANE UNIVERSITY

I. Abstract

The observations reported in the present paper result from investigations by the students at the Tulane University Summer Field Camp in Geology during the years 1960-1962. The area involved is in the front range of the Sierra Madre Oriental of Mexico and includes the well-known Cañon de la Huasteca and the valleys immediately to the south, locally known as the Valle de San Paulo and the Valle de Muralla.

The area is a segment of the Los Muertos anticline whose core consists of the Upper Jurassic Zuloaga Limestone, which is much deformed and locally has been intruded by masses of gypsum. Overlying is a 1200 foot sequence of shales and siltstones that have Portlandian, Upper Jurassic fossils in the lower portion; these are here named the Muralla Shale. Gradationally above are almost 1200 feet of arkosic sandstones and arkose with minor conglomerates that contain an Upper Jurassic fauna, and are here named the San Paulo Sandstone. These two new formations are referred to the La Casita Group.

Lower Cretaceous formations represented include the Taraises Formation in which two members can be recognized. The basal member, consisting of approximately 200 feet of shale and highly fossiliferous limestone is here named the Los Nogales Member. This member is of late Valangian and/or early Hauterivian age, and rests on the San Paulo Sandstone with, apparently, a paraconformable contact.

The main mountain ridges bordering the valleys are composed of the rudistid-bearing Cupido Limestone, 2300 feet thick, the very fossiliferous, marly La Peña Formation, 50 to 100 feet thick, and the thick-bedded Aurora Limestone, incomplete sections of which form the outer flanks of the Los Muertos anticline.

Near the western end of the Valle de Muralla an isolated mass of Tertiary (?) clay rests upon the eroded edges of the Taraises Formation. The clays are believed to represent lacustrine deposition, but a wholly satisfactory explanation of their occurrence has yet to be advanced. Alluvium and colluvium, some of it cemented with caliche, masks the floors and lower slopes of the valleys.

There is stratigraphic evidence of an east-west trending fault along the floor of the Valle de San Paulo to the south of the present outcrop trend of the Zuloaga Limestone; it is suggested that movement along this fault may have been a contributory factor in the gypsum intrusions into the adjacent Zuloaga Limestone.

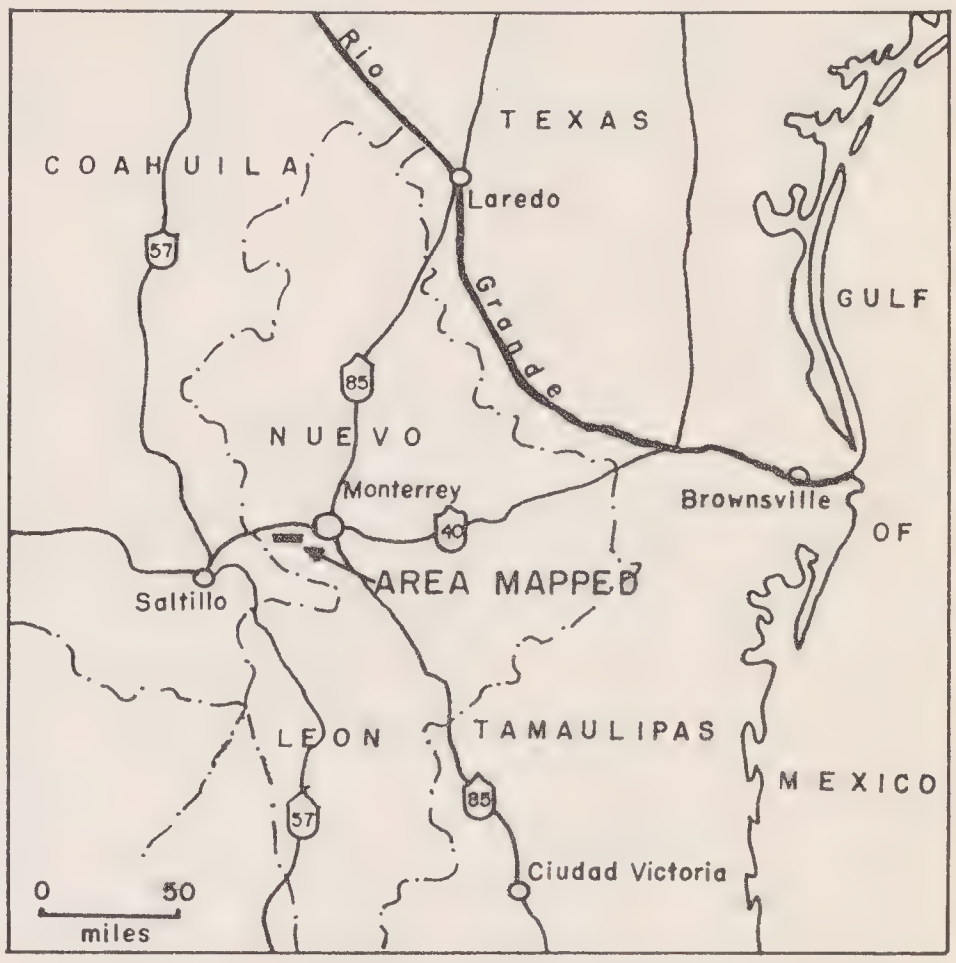

Figure 1. Geographic Location of the Huasteca Cañon Area.

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II. Introduction

> "The geology and stratigraphy of the mountains in northeast Mexico are still almost absolutely unknown; even in late years the mighty ranges and deep canyons of the Sierra Madre Oriental east of Saltillo and south of Monterrey have scarcely even been crossed by a geologist and much less been studied." (Böse, 1923, p. 127)

The fact that the above statement is almost as true today as when it was first made, forty years ago, is justification for the following detailed notes on the geology of a small part of this region. The observations here recorded result from investigations carried on by students attending the Tulane University Summer Field Camp in Geology during the years 1960-1962. Included are details of a number of stratigraphic sections through the formations represented, with description of two new Upper Jurassic formations and one new member of the Lower Cretaceous Taraises Formation.

The area involved in the study is a part of the front range of the Sierra Madre Oriental of Mexico, and includes the well-known Cañon de la Huasteca and the valleys immediately behind it (see fig. 1). It lies immediately southwest of Monterrey, Nuevo Leon, and is south and southeast of the town of Santa Catarina, from which a paved road may be taken to the entrance of the Huasteca.

Structurally the region is part of the Los Muertos anticline, the most northerly of the several folds that constitute this portion of the Sierra. The valley of the Rio Santa Catarina bisects this major structure in the mapped area and the water gaps of the main channel form the Cañon de la Huasteca on the north flank of the anticline and the Cañon de Morteros on the south. The core of the anticline has been eroded to form a moderately broad east-west valley traversed by intermittent streams tributary to the Santa Catarina. The tributary valley west of the main river channel is locally known as the Valle de San Paulo and that to the east constitutes the Valle de Muralla. These names are here adopted and utilized as the geographic element in the names of the two new formations here proposed.

The writer first became interested in the Huasteca area early in 1960 when the late Commodore Penn L. Carroll (U.S.N., retired), at that time advisor to the Rector of the Instituto Tecnológico y de Estudios Superiores de Monterrey, suggested that the geological faculty of Tulane University consider the feasibility of utilizing the facilities of the Instituto as headquarters for a summer field camp. A short visit to the area during the Easter period of that year was sufficient to demonstrate that the region had much to offer geologically, and that the facilities of the Instituto would afford a superlative base for a summer camp. The only obvious drawback was the lack of topographic map coverage; but, aerial photographs were available. It was concluded that the superior exposures of the geologic section in this almost unstudied area offered many projects for student theses and dissertations which with the available aerial photographs more than offset the lack of topographic coverage. Subsequent experience, in which we have combined plane-table topographic and geologic mapping, has demonstrated that there are some advantages in that experience thus gained gives the student confidence in his ability to handle any mapping problem, with or without base maps.

A "test-run" of the camp and the field area was made in the summer of 1960 with four students; in 1961 the student number was increased to seven, all of whom were graduate students at Tulane; and in 1962, both graduate students and seniors from Tulane and other schools participated in the program. The following report and geologic map are based in large measure upon the work of these groups.

III. Acknowledgments

The writer wishes to acknowledge his sincere indebtedness to the late Commodore Carroll for calling our attention to the region as a possible site for the field camp, and also for his vigorous assistance in advancing the work of the group in the Monterrey area. Many local geologists, who were made aware of our project through Commodore Carroll's interest gave much helpful assistance and advice; all cannot be separately mentioned and thanked here, but I cannot fail to express our deep appreciation for the hospitality and courtesies extended to us and our students by Mr. Walter H. Triplett, former chief geologist for the Compania Mineria de Peñoles, S. A.

The officials at the Instituto Tecnológico have proved unflaggingly helpful and anxious to advance the work of the camp. All cannot be thanked individually, but special mention must be made of Ing. Fernando García Roel, the Rector of the Instituto and companion in the field when his official duties permit. To him, as well as to Ing. Francisco Mancillas, Dean of the Escuela Verano, to Mr. Harold Wise, Assistant to the Dean, and to Colonel Carter Hilsabeck (U.S.A., retired), successor to Commodore Carroll, go our sincerest appreciation for their efforts in behalf of the camp project.

Finally, the present writer must express his very real indebtedness to the students whose field work is here utilized, and whose project reports are freely employed; they have made the present report possible. Included in the group of 1960 were: James A. Holliday, Anthony T. L'Orsa, Arthur D. Piaggio and Emily H. Vokes, all from Tulane University. The 1961 group included: Robert F. Beyer, Jr., Victor V. Cavaroc, Jr., William E. Daughdrill, Gerald C. Glaser, Harold J. Morrow, John Sandy, Jr., and Albert P. Selph III. 1962 participants were Theodore T. Gittinger, Gary O. G. Greiner, and Louis A. Oswald, Jr., all from St. Mary's University at San Antonio, Texas; Mr. Joshua H. Rosenfeld, a former graduate student at Louisiana State University; and Leland Dennis II, a senior, and Harold J. Morrow, a graduate student from Tulane. Mr. Piaggio of the 1960 group and Mr. Morrow in 1962 were engaged in work on field projects for their Master of Science theses.

Previous Work

Although the Huasteca area has long been known as a scenic attraction, either under that name or as the Cañon de Santa Catarina, the first significant mention of the geology of the region was by Böse in 1923 (his introduction to that paper is quoted above). Böse sketches the general stratigraphic sequence and publishes (p. 200) small diagrammatic cross-sections, one of which probably would cross the area of the present geologic map. Böse and Cavins (1928, p. 17-18) note the occurrence of "sandstones and conglomerates of the Portlandian (Jurassic)" and of limestones and marls of "Infracretaceous" and "Mesocretaceous" age. They also give rough estimates of the thicknesses of some of the deposits and list characteristic fossils from certain units; but, as in the earlier paper, they do not apply local formational names to the units observed.

Finally, Humphrey (1949) makes passing mention of certain of the formations present in this region while he is discussing the stratigraphy of the Cortinas Canyon area and the western part of the Los Muertos structure.

IV. Stratigraphy

General Statement.—The geologic section exposed in the Los Muertos anticline within the area of the present study consists primarily of sediments of upper Jurassic and lower Cretaceous age. Resting upon these near the village of Los Nogales is a small deposit of clay of Tertiary or post-Tertiary age; elsewhere a mantle of Quaternary or Recent alluvium and colluvium covers the valley floors and extends for some distance up the adjacent slopes. The stratigraphic sections of the Mesozoic rocks exposed in the two flanks of the anticline are shown in figure 2. The term, "Los Nogales Member of the Taraises Formation," was proposed by Piaggio in 1962 (unpublished M.S. thesis, Tulane University). The San Paulo Sandstone and the Muralla Shale are new formation names here first proposed.

Jurassic System

Sabinas Series[1]

Zuloaga Stage

Zuloaga Limestone

The term Zuloaga Limestone was proposed by Imlay (1938, p. 1675) to designate the offshore equivalent of the La Gloria formation with the type locality in the Sierra Sombreretillo, north of Melchor Ocampo, on the Coahuila-Zacatecas border. Here there are about 1800 feet of gray limestone, mainly thick-bedded. Most of the complete sections known elsewhere appear to be thinner. The beds so named by Imlay are those that had previously been referred to as the "*Nerinea* limestone" or the "Gray limestone with *Nerinea*" by Burckhardt (1906; 1930) and by Böse (1923).

[1] For a discussion of the origin and history of the "series" and "stage" names used in this report, see Murray, 1961, pp. 287-8; 292; 297-301; 307-8.

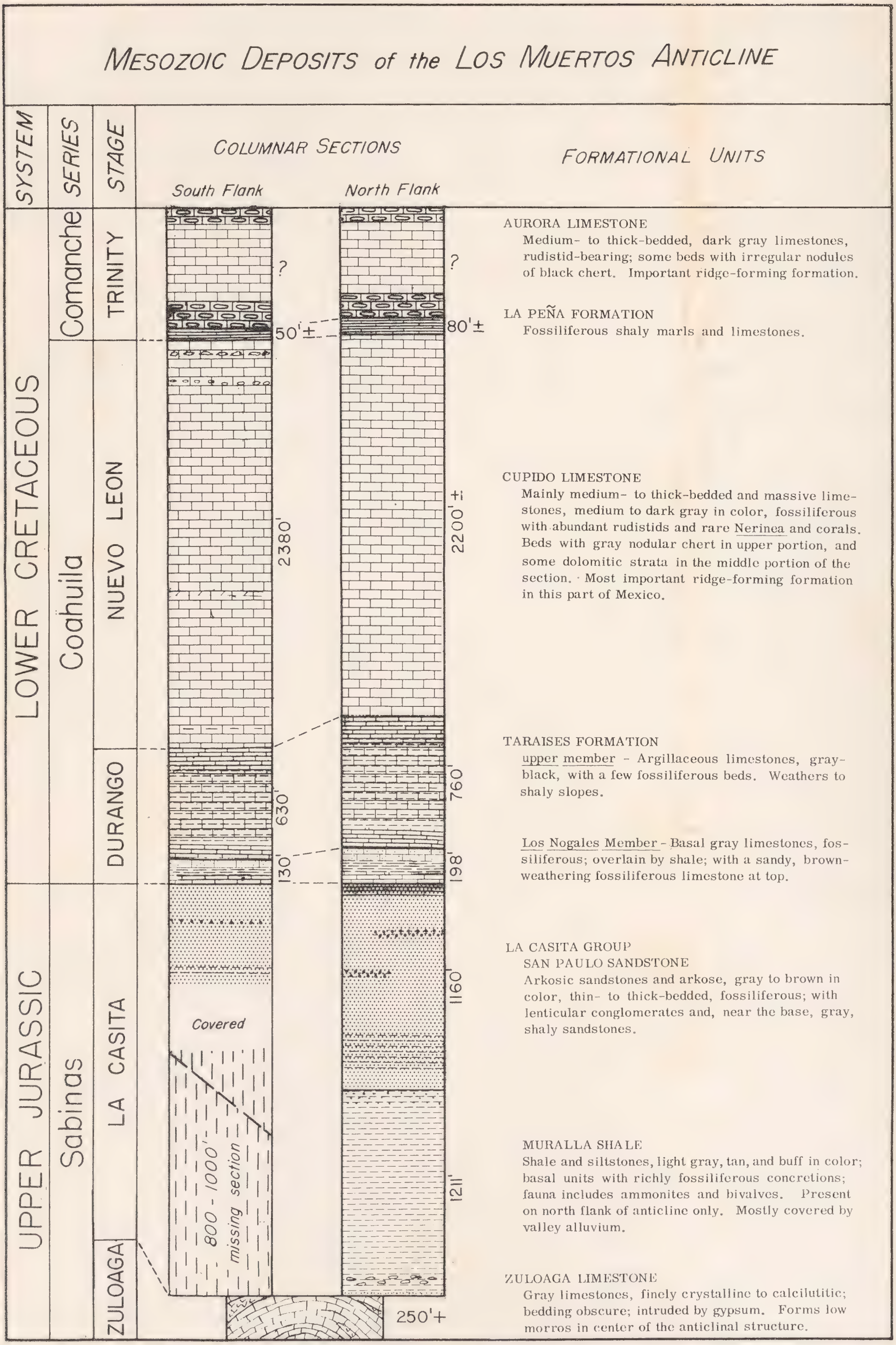
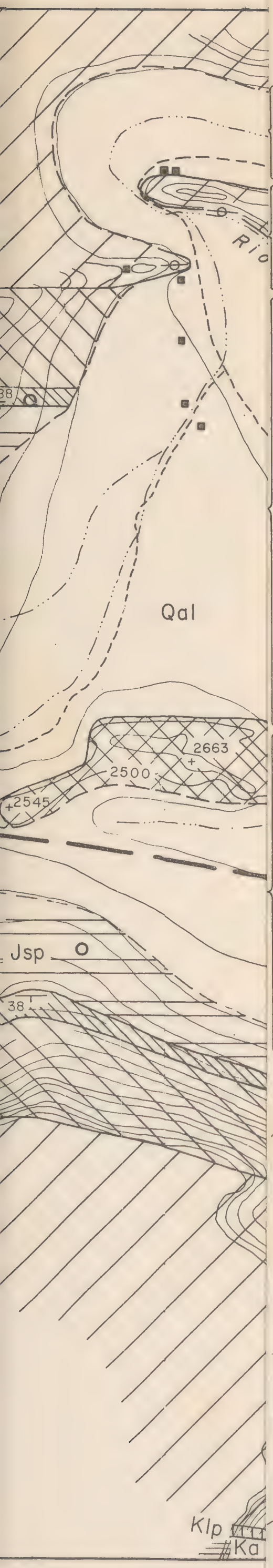


Figure 2. Stratigraphic columns comparing the Mesozoic deposits cropping out on the north and south flanks of the Los Muertos Anticline.



EXPLANATION

Qal — alluvium

T or Q(?) — "enigma" clay

Ka — Aurora Limestone

Klp — La Peña Formation

Kc — Cupido Limestone

Kt — Taraises Formation
upper member - Kt
Los Nogales Member - Ktln

Ktln

Jsp — San Paulo Sandstone } La Casita Group

Jm — Muralla Shale } La Casita Group

Jz — Zuloaga Limestone

Bedding; inclined, vertical, and overturned

Fossil locality

Surveyed elevation

Trail

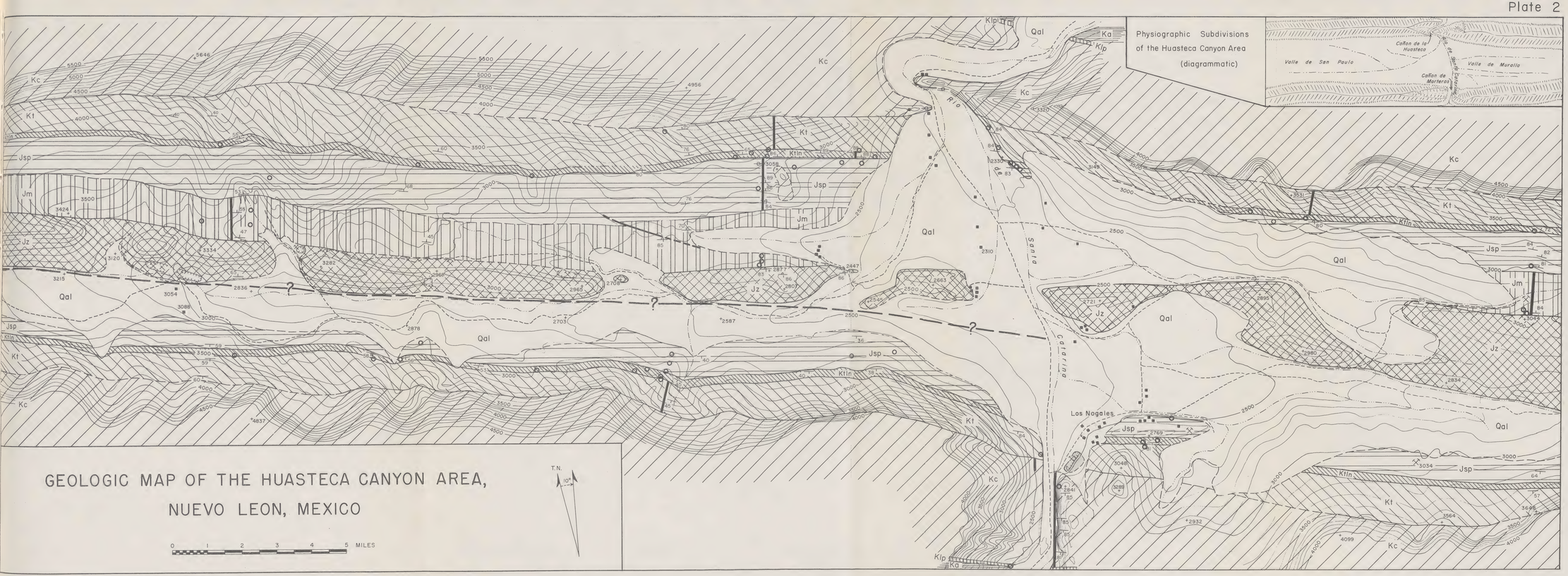
Intermittent stream

Measured section

Quarry and mine

3000 — Contours on valley floor and lower slopes; contour interval 100 feet

Plate 2



GEOLOGIC MAP OF THE HUASTECA CANYON AREA, NUEVO LEON, MEXICO

T.N. 10°

0 1 2 3 4 5 MILES

Physiographic Subdivisions of the Huasteca Canyon Area (diagrammatic)

EXPLANATION

- Quaternary
  - Qal — alluvium
- Tertiary or Quaternary
  - T or Q(?) — "enigma" clay
- Cretaceous
  - Lower
    - Ka — Aurora Limestone
    - Klp — La Peña Formation
    - Kc — Cupido Limestone
    - Kt — Taraises Formation
      - upper member - Kt
      - Los Nogales Member - Ktln
  - Upper Jurassic
    - Jsp — San Paulo Sandstone
    - Jm — Muralla Shale
    - (La Casita Group)
    - Jz — Zuloaga Limestone

Bedding; inclined, vertical, and overturned

Fossil locality

Surveyed elevation

Trail

Intermittent stream

Measured section

Quarry and mine

3000 Contours on valley floor and lower slopes; contour interval 100 feet

The Zuloaga Limestone crops out in the mapped area in a series of isolated hills, or morros that are aligned in a strike ridge along the core of the Los Muertos anticline. It consists of thin- to thick-bedded gray limestones, generally finely crystalline, but with some strata of typical calcilutitic texture. The rock has been much fractured and deformed in the folding until bedding planes are almost wholly obscured and consequently it has not been possible to obtain adequate measurements as to the thickness of the exposed sequence. Numerous small calcite and quartz veins cut the rock. Locally, the secondary calcite veins are sufficiently well developed to be quarried for chips utilized in terrazzo and other ornamental purposes. The limestone weathers to a dull gray tone and the surface is characteristically marked with deep solution grooves and pits.

Humphrey (1949, p. 95) described the limestones in the western part of the Sierra de Los Muertos, near the Nuevo Leon-Coahuila state boundary as containing "abundant gray, rust-weathering chert in the form of elongate lenses and irregularly shaped nodules." In the area presently under study chert is a relatively rare feature, although what few fossils have been found have all been silicified and weather to a rust color.

In the Valle de San Paulo area there are a number of small lenticular bodies of gypsum intrusive into the Zuloaga Limestone. They occur sporadically on both the northern and southern limbs of the anticlinal structure and characteristically underlie a zone of gray to tan colored, calcilutitic limestone that is sufficiently dense to break with a conchoidal fracture. The largest of the gypsum masses within the area investigated has a length of approximately 1,500 feet and a maximum thickness of about 150 feet. This mass has been extensively quarried and the quarry walls and faces exhibit a number of features clearly demonstrating the fact that there has been considerable flowage of the gypsum during the folding of the anticline. Streaks and zones of gypsiferous clay, suggestive of original bedded impurities, are strongly distorted, thickened and thinned, but in general have dips within the central part of the mass that diverge from the dips of the enclosing limestone at angles ranging up to 70°. Adjacent to the limestone borders, however, these clay stringers tend to assume dips almost parallel to those of the limestone. The surfaces of the limestone strata in the gypsum contact zone are covered with a plaster of gypsiferous clay that exhibits many evidences of plastic flow with streaks and striations indicating that the movement was generally almost vertical in respect to the present attitude of the beds, and hence toward the apex of the anticlinal fold.

Wall, Murray and Díaz (1961) describe gypsum intrusive through the Zuloaga Limestone into the La Casita Group in the Sierra del Fraile area, about 30 kilometers to the north of the present occurrences. Drilling within the Sierra del Fraile anticline revealed a core of gypsum underlain by salt. According to Wall *et al.* (1961, p. 1508): "A salt test drilled . . . in Potrero García (southern part of Sierra del Fraile) was bottomed at 3,700 feet without penetrating all of the evaporitic section. Except for 100 feet of surficial deposits, the upper 2,100 feet consisted of gypsum and anhydrite with some pyrite and hematite. From 2,100 to 3,100 feet the section was composed of interbedded gypsum, anhydrite, and salt. Below 3,100 feet salt with minor impurities was encountered." This sequence of evaporites has been referred to as the "Minas Viejas formation," a term first used in a correlation table by Humphrey in 1954. The term has been used subsequently by a number of authors (Humphrey, 1956; de Cserna, 1956; Díaz, 1956; Wall *et al.*, 1961). According to Wall *et al.* (1961, p. 1506, fft.): "Formal description of the Minas Viejas sequence and designation of a type locality in the Sierra de Minas Viejas will be made by W. E. Humphrey in a forthcoming paper on the geology of northeastern Mexico." The most complete statement that has been published to date is that of de Cserna (1956, p. 16):

> "Yeso Minas Viejas.—Este nombre ha sido propuesto de manera informal por Hunphrey [*sic*] (1954, tabla 2), para designar estratos de yeso, así como de lutitas, limolitas y arseniscas, principalmente de color rojo, que subyacen a la caliza Zuloaga en los anticlinales de las cercanías de Monterrey. . . . Dentro del área del mapa, el yeso Minas Viejas aflora en el núcleo de la parte oriental del Anticlinal de Los Muertos, al sur de Santa Catarina, cerca de Monterrey. Debido a este afloramiento, así como al cercano a Galeana, y la estructura

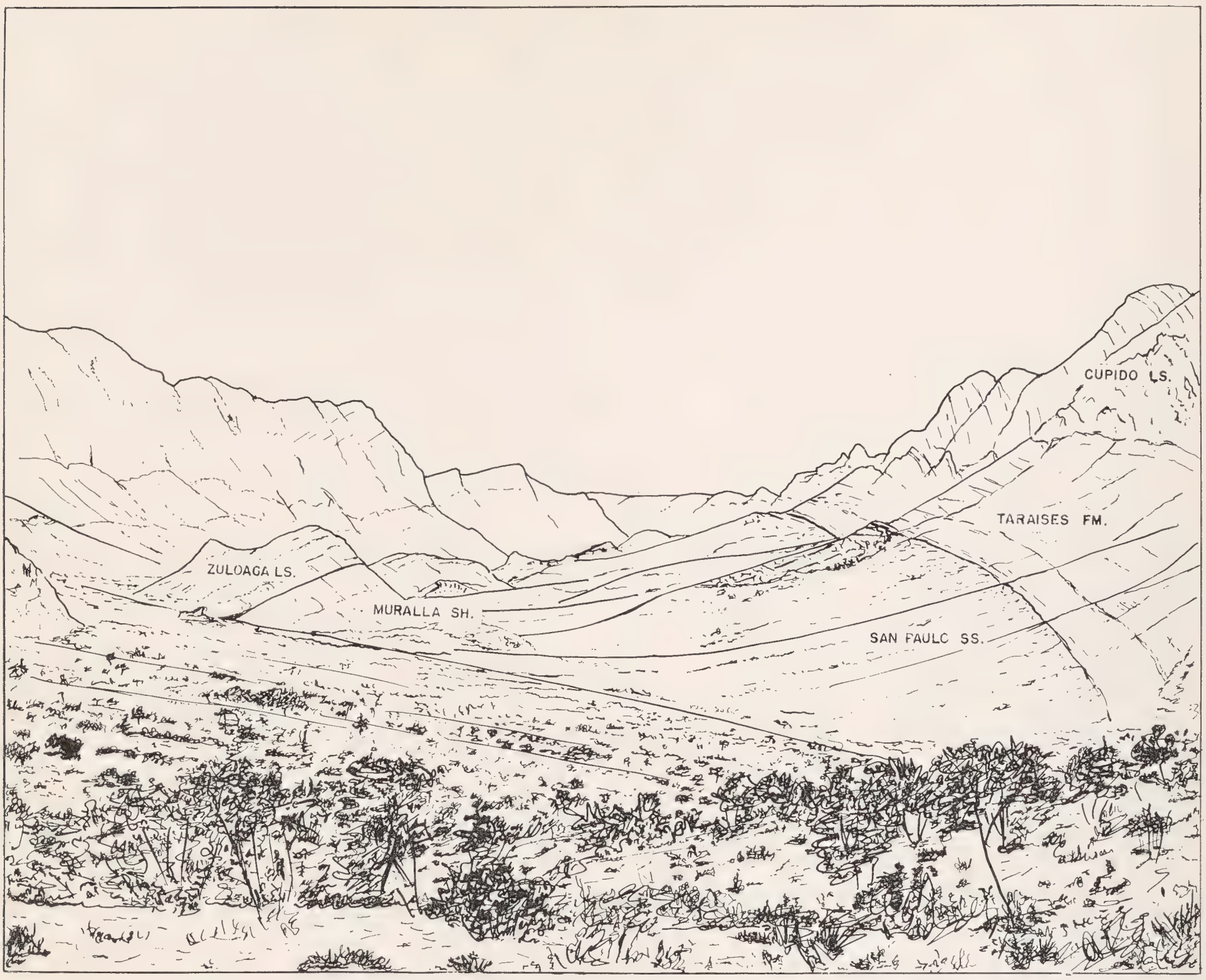


Figure 3. Valle de San Paulo; view looking westward along the north side of the valley from slopes immediately above east side of Rio de Santa Catarina.

característica del Anticlinorio de Arteaga, el autor considera que el yeso Minas Viejas subyace a dicho anticlinorio y que otros afloramientos de esta unidad, serán revelados con estudios posteriores más detallados.

"Por su posición estratigráfica, el yeso Minas Viejas se considera perteneciente al Divesiano; su desarrollo ha sido controlado por la proximidad relativa del mar y por las condiciones climatéricas prevalecientes durante su depósito."

La Casita Stage

La Casita Group

In 1936 (p. 1110) Imlay described a La Casita Formation to include "the shales, sandstones, and intercalated limestone beds lying between the La Gloria formation (below) and the Taraises formation (above)." The type locality was designated as Cañon de la Casita, located about 10 miles south of General Cepeda and about 30 miles southwest of Saltillo. The type region was described in 1937 (pp. 601-2) with measured sections, varying from 240 to 285 feet in thickness. Two lithologic members were recognized: a lower one that "consists of gray conglomeratic sandstone and ranges in thickness from about 20 to 75 feet or more. At the top, in most sections, are a few inches of friable sandstone, which contains brachiopods bivalves, and belemnites. The upper member consists principally of black shales but includes some buff or gray sandy shales, short lenses of sandstone and arenaceous limestone, and lenticular limestone nodules. Some of the nodules contain well-preserved mollusks." The formation was stated (p. 604) to be of Kimmeridgian and Portlandian age. "The basal sandstones may be of Oxfordian age."

Subsequent work has revealed much lithologic variability in the sequence of strata that occupies the position of the La Casita Formation. In 1956 Humphrey and Díaz, in a table giving the "Correlation of the Mesozoic Strata of Northeast Mexico"

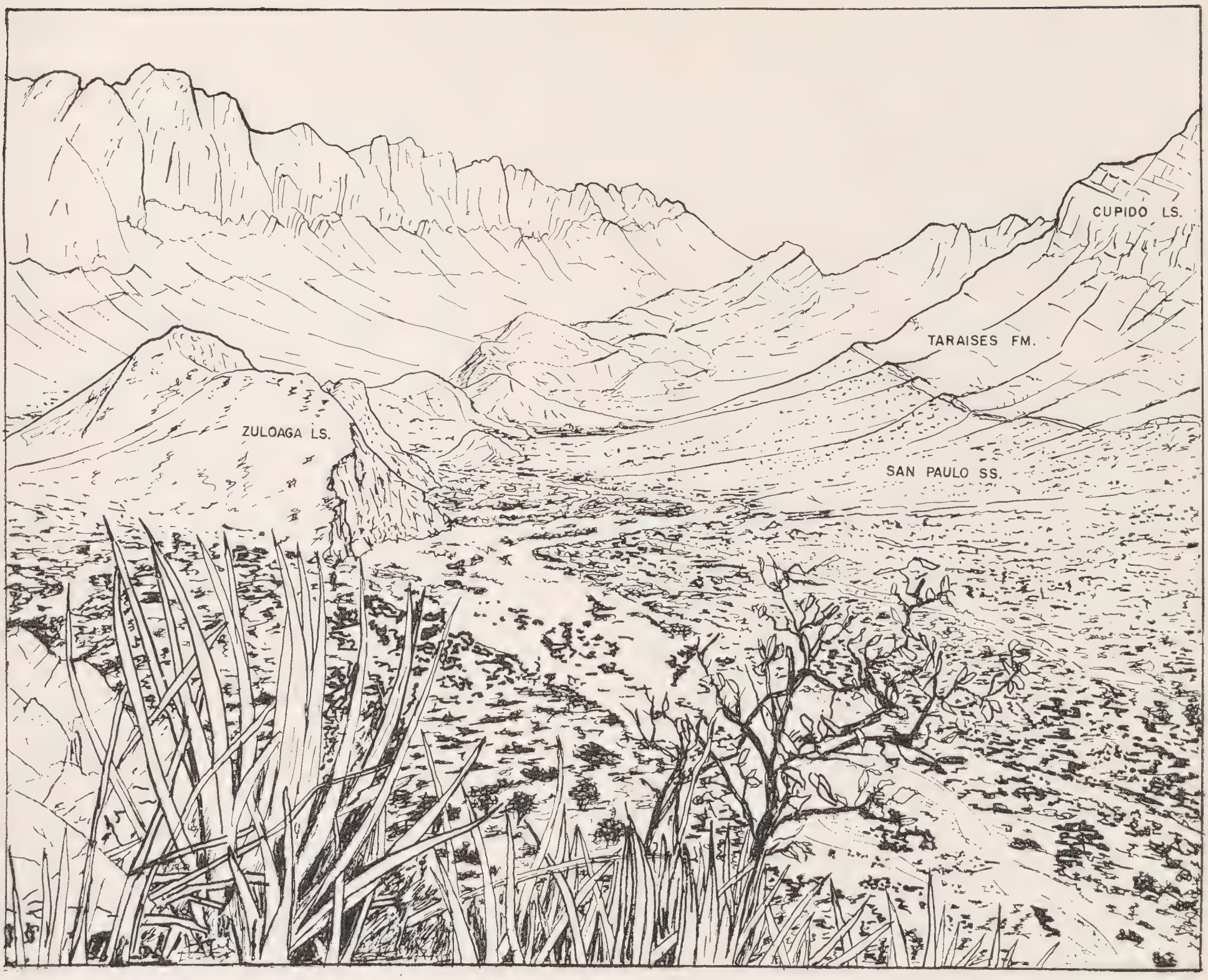


Figure 4. South flank of Los Muertos Anticline; view showing east end of Valle de San Paulo and the Valle de Muralla.

(see Humphrey, 1956, pp. 32-34) used the term "La Casita group" to specify the Jurassic strata of varying lithology that overlie the Zuloaga or La Gloria formations. Murray (1961, p. 292) pointed out that the term as thus applied was in a time-rock sense and added "Because these strata are exposed and well known in northeastern Mexico, inasmuch as they are laterally continuous with strata in the coastal province of Mexico and the United States, and because they are reasonably accessible, La Casita is used herein as a provincial stage for the youngest known late Jurassic in the coastal province to include rocks which can be equated in any reasonable way to typical La Casita and La Caja sequences." It is to be noted that this usage, since it includes strata that contain fossils of Tithonian age, is an extension of the range of the La Casita Formation at its type locality.

Within the Los Muertos anticline the deposits of the La Casita stage have a thickness varying from 2200 to 2400 feet and are readily divisible into two units which were designated as "members" of the La Casita Formation by Humphrey (1949, pp. 97-100) but which are here raised to the rank of formational units. The lower, herein denominated the Muralla Shale varies in thickness from 1164 to 1211 feet in sections measured in the region of the present study; it appears to be essentially correlative with the La Casita Formation of Imlay at its type area. The upper formation, here named the San Paulo Sandstone, consists mainly of fine- to coarse-grained, usually arkosic sandstones, with a number of lenticular conglomeratic horizons and occasional beds and lenses of very sandy limestones. Measured sections give thicknesses varying between 1130 and 1255 feet. A large fauna of pelecypod Mollusca is present together with a few sandstone casts of ammonites. The general faunal evidence seems to suggest that this unit is

probably of upper Portlandian and Tithonian age.

Muralla Shale

Definition.—The name Muralla Shale is here applied to a sequence of sandy to silty shales and thin-bedded siltstones with occasional beds of highly argillaceous limestone and, toward the upper part, a few fine grained sandstones that generally are calcareous and more resistant to erosion than the adjacent shaly strata. Zones of dark gray limestone concretions occur within the lower 250 feet of the formation; these contain abundant Kimmeridgian ammonites and occasional pelecypods, including *Aulacomyella neogeae* Imlay. Certain horizons within the silty shale sequence also have compressed and flattened casts of ammonites some of which appear to represent species of *Idoceras.* The type section is in the Valle de Muralla, on the north flank of the Los Muertos anticline approximately two and one-quarter miles east-northeast of the school house at Los Nogales. An almost completely exposed section may be seen northward from the contact with the Zuloaga Limestone on the northern side of hill 3044.

Stratigraphic and lithologic features.—The non-resistant nature of the sediments comprising the Muralla Shale has resulted in a general dearth of exposures. Over much of the area studied, the formation is topographically lowest in the erosional valleys flanking the row of Zuloaga morros in the central part of the Los Muertos structure, and consequently the strata are buried under a cover of valley alluvium and colluvium. No outcrops of the Muralla have been found on the south limb of the anticline and there is reason to believe that the formation may be missing here due to strike faulting along or near the anticlinal crest; this will be discussed in a later part of this report. The most completely exposed sections are located on the north limb of the structure near the eastern and western limits of the mapped area, where the streams tributary to the Rio Santa Catarina have not eroded their courses as deeply as they have near their confluence with the main stream channel.

The section at the type locality, measured by Gary O. G. Greiner and the writer includes the following units:

Unit		Feet
5.	Finely laminated siltstones and silty fissile shales, gray to brownish-gray in color, weathering to buff. The lower 500 feet with gypsum beds in veinlets, but with occasional beds up to one foot in thickness. No fossils found	782
4.	Shale and finely laminated silts, pinkish to buff in color, weathering light gray. Occasional gypsum in bands ¼ to ½ inch thick. Unfossiliferous	52
3.	Siltstones in beds up to 12 inches thick with interbedded silty shale. Color light-gray, weathering white. Thin beds of limonite interbedded from 44 to 48 feet above the base. Unfossiliferous	76
2.	Shale, pink to pinkish buff in color, punky in texture, weathers to fine chips, light to medium gray in color. A bed of black colored silt 70 feet above base. A few indeterminate outlines of compressed ammonites observed on bedding surfaces	170
1.	Shale, and thin shaly siltstones, light gray to buff in color, weathering buff. Occasional zones of gray calcareous concretions, up to one foot in diameter; one 85 to 90 feet above the base with abundant ammonites and occasional pelecypods and petrified wood. Some of the concretions in this zone when broken reveal cores, or marginal zones of limonitic dust. Aptychi and flattened ammonites occur on shale bedding planes both above and below the zone	131
		1,211

A section approximately seven miles to the west of the type area was measured by W. E. Daughdrill, H. J. Morrow and John Sandy, Jr., of the 1961 field group. This section, which is located toward the western end of the mapped area, follows:

Unit		Feet
14.	Calcareous shales and shaly limestones, tan to gray in color, weathering to gray shale slopes. About 420 feet above the base there	

Unit		Feet
	is a 12 ft. zone with calcite veins 4 to 6 in. thick, suggestive of mineralization along folding glide planes. Unfossiliferous	640
13.	Tan to gray silty calcareous shales with occasional gray fine-grained sandstones, weathering brown, and more resistant to erosion, forming ledges. Unfossiliferous	103
12.	Sandstone, fine-grained, dense, calcareous, light brown in color, weathers to form a rusty brown ledge; no fossils	3
11.	Shale, calcareous, light gray, unfossiliferous	37
10.	Sandstone similar to unit 12	7
9.	Silty shale and siltstone, thin-bedded, light brown in color, with a very few, thin, fine-grained sandstone interbeds. Unfossiliferous	123
8.	Sandstone, light gray, weathering to rusty brown, fine- to very fine-grained with calcareous cement	11
7.	Shale, light buff to light gray in color, with local beds and lenses of hard calcareous black shale. Selenite veins and crystals common	14
6.	Sandstone, as in unit 8	2.5
5.	Shale similar to unit 7	68
4.	Sandstone, calcareous, fine- to very fine-grained, light brown in color, weathering dark brown	3
3.	Shale, light gray, buff to white in color, with some zones and lenses of black shale; resembles a diatomaceous shale; selenite abundant on bedding planes; fossils sporadically abundant on the bedding planes, especially in the light gray colored beds, including aptychi, flattened unidentifiable ammonites and pelecypods, fish scales and occasional leaf fragments	27
2.	Calcareous shale, light gray to buff in color, with occasional thin (3 to 6 in.) fine-grained sandstone or siltstone interbeds; selenite veins common; calcareous concretions, often with ammonites, occurring in zones toward the upper part of the unit; the uppermost foot marked by abundant, rather large concretions (averaging 14 x 10 x 4 in., and flattened along the bedding plane) usually containing numerous small ammonites	132
1.	Covered interval to the Zuloaga Limestone	32
		1,202.5

The contact of the Muralla Shale with the underlying Zuloaga Limestone has been observed only on the north side of the second morro (elev. 2877 ft.) west of the Rio Santa Catarina. There the basal bed of the Zuloaga is overturned, dipping 83° S. Although the contact is conformable, a stratigraphic break is suggested because the basal unit of the Muralla consists of a 6 inch bed of highly sandy limestone overlain by a 6 inch bed of coarse, poorly sorted grit. The slope of the hill down to the stream channel which interrupts the section, reveals 291.5 feet of strata, mainly buff to orange-buff claystone and silty mudstone. Ammonites and aptychi have been found in the claystones 15 and 70 feet above the base; in a 1.5 foot, black calcareous sandstone 87 feet above the base; in calcareous concretions 192 to 198 feet above the base, and in claystones 220 feet above the base.

San Paulo Sandstone

Definition.—The name San Paulo Sandstone is here applied to a sequence of fine- to coarse-grained calcareous sandstones and sandy limestones that include numerous sporadic lenticular conglomerates. The type section is exposed in the first draw west of a ridge north of the second morro west of the Rio Santa Catarina (see above). This ridge is easily recognized by a cap of a large collapsed mass of Cupido Limestone that rests upon the San Paulo Sandstone. The type section includes 1,160 feet of beds; Humphrey (1949, pp. 98-9) gives a measured section of his "upper member" of the La Casita Formation which includes 1,190 ft. of strata.

Stratigraphic and Lithologic features.—The San Paulo Sandstone is composed primarily of marine arkosic sandstone and arkose, but its most characteristic feature is the great amount of lithologic variation, both laterally and vertically; no two sections are alike in sequence, and individual units prove to be

highly lenticular, changing rapidly in thickness, color and grain size along the strike. Sandstones, so highly calcareous as almost to merit designation as arenaceous limestones are replaced by pebble conglomerates within a few hundred yards along the strike. Conglomerate lenses three feet thick have an outcrop length of less than two hundred feet and pebbles as much as two inches in greatest diameter.

The type section, measured by the writer and his wife, Emily H. Vokes, follows:

Unit		Feet
40.	Marl, silty, very soft, light gray, weathers yellow	2
39.	Limestone, sandy, dark gray, weathering medium gray, lower half mottled brownish with much disseminated siderite	3
38.	Sandstone, arkosic, coarse-grained, very calcareous, dark gray, weathering a medium brownish gray; one bed	8
37.	Sandstone, arkosic, medium to coarse-grained, calcareous, much disseminated siderite (?), brownish gray, weathering brown; bedding obscure; many small vugs with calcite and quartz crystals	32
36.	Arkose, medium-grained, noncalcareous, pale yellowish brown in color, weathering a slightly lighter tone; thin-bedded and much jointed	13
35.	Arkose as in unit 36, but massive bedded and calcareous, lower 2 ft. with abundant pelecypods including *Trigonia* and *Pholadomya* (?), in matrix too hard to permit collecting	15
34.	Sandstone, slightly arkosic, noncalcareous, medium to coarse-grained, with small disseminated siderite nodules, light olive gray, weathering medium light gray; in one massive bed	10
33.	Arkose, as in unit 35, but one massive bed with a few scattered fossil fragments	16.5
32.	Sandstone, very arkosic, calcareous, medium-grained, dark gray, weathering brownish gray; casts of large pelecypods (indeterminate) near base	41
31.	Sandstone, very arkosic with abundant disseminated mica flakes, calcareous, dark gray, weathering dark brownish gray; contains abundant specimens of *Exogyra* sp.; *Gresslya* and "*Lucina*" present	8
30.	Sandstone, arkosic, noncalcareous, medium- to fine-grained, dark yellowish brown, weathering light yellowish brown, thin-bedded and much fractured with calcite veins	15
29.	Sandstone, fine-grained, well-sorted, noncalcareous, medium light gray in color, weathering rusty brown, with a very hackly fracture	6
28.	Sandstone, arkosic, coarse-grained to a grit conglomerate, dark gray, weathering dark brown; fossiliferous, fauna includes *Berriasella* (?) sp., *Exogyra* cf. *E. potosina* Castillo & Aguilera, and *Trigonia* n. sp., aff. *T. vyschetzkii* Cragin, *Nerinea* sp.	7
27.	Sandstone, arkosic, fine to medium grained, light olive gray, mostly noncalcareous, but with scattered calcareous zones which weather in a manner suggestive of concretions or boulders up to 6 in. in diameter	16
26.	Sandstone, fine- and medium-grained, medium gray, weathering medium light gray, in beds up to one foot thick, much fractured; *Exogyra* sp., *Pinna* cf. *P. quadrifrons* Cragin	11
25.	Sandstone, arkosic, similar to unit 27; *Exogyra* sp.	17
24.	Silty shale, dark gray to black, weathers to pencil-cleavage like fragments	10
23.	Sandstone, as in unit 29	1.5
22.	Sandstone, fine-grained, hard, calcareous, medium gray, weathering brownish gray; one massive bed; fossiliferous; *Pleuromya* ? cf. *P. inconstans* Castillo & Aguilera	4
21.	Sandstone, fine- to medium-grained, light to medium gray, weathering gray brown; in two hard beds, the lower of which has scattered quartz grains up to 2 mm in diameter	7.5
20.	Conglomerate, and coarse gritty sandstone with scattered pebbles of quartzitic and rhyolitic (?) composi-	

Unit		Feet
	tion; fossiliferous with unidentifiable Pelecypoda	2
19.	Sandstone, similar to unit 27, but wholly noncalcareous, massive bedded	27
18.	Sandstone, fine- to very fine-grained, noncalcareous, shaly, medium light gray, weathering light gray	21
17.	Sandstone, medium- to coarse-grained with lenses of grit conglomerate, calcareous, medium dark gray, weathering brownish gray, scattered fossil fragments, *Exogyra* sp.	31
16.	Arkose, coarse-grained, variegated dark gray and olive gray, weathers light olive gray	9
15.	Sandstone, arkosic, with much disseminated siderite (?), light olive gray, fine-grained below becoming more coarse-grained, almost a fine conglomerate at top	33
14.	Sandstone, fine-grained, noncalcareous, medium to dark gray, weathering very dark gray	23.5
13.	Sandstone, similar to unit 15; *Gresslya* sp.	12
12.	Sandstone, arkosic, fine-grained, noncalcareous, medium gray to medium dark gray, weathering medium gray	15
11.	Conglomerate, with quartz pebbles 5 to 10 mm in diameter, medium gray, weathering light gray	2.5
10.	Sandstone, similar to unit 12, with lenses of gritty conglomerate, and a conglomerate lense 8 inches thick 25 ft. below the top with fractured chert pebbles up to 2 in. in diameter	85
9.	Sandstone, very poorly sorted, fine- to very coarse-grained, locally conglomeratic, the coarse sand grains and the pebbles in the conglomeratic lenses of chert and quartz, noncalcareous, medium light gray, weathering dark yellowish brown; casts of *Gresslya* (?) 24 to 26 ft. above base	66
8.	Arkose, medium- to fine-grained, medium dark gray, weathering light brownish gray, moderately thick-bedded; interbedded with arkose, thin-bedded, fine to very fine-grained, noncalcareous, medium light gray, weathering light olive gray	89.5
7.	Sandstone, very fine-grained, noncalcareous, medium gray in color, thin-bedded and strongly jointed, weathering to coarse "pencil structure" fragments	27
6.	Arkose, similar to the medium-grained units in 8, moderately thick-bedded	51
5.	Sandstone, very fine grained, as in unit 7	32
4.	Sandstone, very fine grained and silty, slightly calcareous, thin-bedded and much fractured with calcite veins	128
3.	Siltstone, noncalcareous, medium dark gray, weathering light yellowish gray, with an 18 in. bed of silty claystone, pale red in color, at the top and three 6 in. beds of similar composition and color interbedded between 16 and 19 ft. from the top	238.5
2.	Sandstone, fine- to medium-grained, micaceous, calcareous, hard, medium gray, weathering brownish gray, in two massive beds, the upper 2.5 and the lower 4 ft. thick separated by 1.5 ft. of siltstone as in unit 3. The two resistant sandstone beds stand as dike-like ridges 18 to 20 feet high on the east wall of the tributary valley along which the section was measured	8
1.	Arkose, medium-grained, micaceous, noncalcareous, medium dark gray, weathering olive gray, thin-bedded and becoming somewhat finer grained toward the base	16
		1,160.5

Stratigraphic relations.—The contact of the San Paulo Sandstone with the underlying Muralla Shale is gradational, the line being drawn where the lithology changes from predominantly silty shale to fine-grained arkosic sandstones. In general the Muralla Shale weathers to a lighter gray tone while the shales of the San Paulo tend to be darker gray, often with a brownish

color derived from the iron content of the arkose impurities.

Fossils and age.—The arkosic sandstones and conglomeratic beds of the San Paulo contain abundant, but usually poorly preserved, pelecypods, including at least three species of *Trigonia,* together with *Gresslya, Pleuromya, Pholadomya, Panopea, "Thracia," "Lucina," Astarte* s.l., *Exogyra,* and *Gryphaea* (?). The gastropods include *Nerinea, "Actaeonella,"* and naticoid forms; the cephalopods, a few ammonites and rare belemnites. The ammonites are usually in the form of sandstone casts which preserve the coarser details of ornamentation, but lack sutures. Ten feet above the base of the formation in its eastern exposures near the type area of the Muralla Shale, a specimen was collected consisting of approximately one-half whorl, marked by a whorl section approximately two-thirds as wide as high, with a rounded venter, and ornamented by moderately strong, slightly prosoradiate ribs that bifurcate approximately half way down the side of the whorl and are directly continuous across the venter. The sum of these characteristics is suggestive of the genus *Berriasella.* Somewhat higher in the section a specimen with rather compressed planulate whorls marked by numerous fine prosoradiate ribs adjacent to the venter and apparently otherwise smooth on the sides, resembles so far as can be determined from its poor preservation, illustrations of species referred to the genus *Proniceras.* A large specimen collected within the upper 30 feet of the section appears to represent a *Kossmatia*-like form. If these fossils be correctly assigned they indicate that the San Paulo Sandstone is wholly of Tithonian age.

Cretaceous System
Coahuila Series
Durango Stage
Taraises Formation

The name, Taraises Formation was proposed by Imlay (1936, p. 1111) for "a limestone formation of Valanginian age, which crops out in the western part of the Sierra de Parras." In the type region the formation ranges from 470 to 487 feet in thickness and is divisible into two members, the upper, 225 feet thick, "consists of thin-bedded limestones and nodular to splintery shaly limestones. Fresh surfaces are light gray or dark gray, and weathered surfaces are light yellowish-gray or cream. Fossils are found throughout but are especially abundant near the base. . . . The ammonite genus *Olcostephanus* (*'Asteria'*) is represented by many species and numerous individuals." The lower member, about 245 feet thick, "consists of gray limestones, and is more resistant to erosion than is the overlying member. Weathered surfaces are an inconspicuous medium gray. Ammonites are found throughout but are abundant only near the top."

In 1938 Imlay summarized the stratigraphy of the Taraises Formation in the northern Zacatecas-southern Coahuila region, and presented a systematic description of the ammonite faunas. He concluded (1938, pp. 550-552) that "in the more southern localities studied" the lower member "contains fossils which indicate both Berriasian and Valanginian ages" but to the north "the presence of *Olcostephanus* in the lowest beds suggests an age not older than the Valanginian." The upper member was regarded as being of lower Hauterivian age.

The deposits correlated with the Taraises Formation in the Valle de San Paulo-Valle de Muralla area are likewise divisible into two members which differ, however, lithologically from the Taraises as developed in its type area. The lower member, furthermore contains, near its base, abundant representatives of the ammonite genera *Acanthodiscus, Leopoldia* and *Distoloceras,* an association which Imlay (1938, p. 552) believes is indicative of a lower Hauterivian age. Hence it is believed that the deposits here referred to the Taraises Formation represent correlatives only of the upper member of the formation as present in its type locality.

The contact of the Taraises Formation with the underlying San Paulo Sandstone is apparently conformable although marked by a sharp lithologic change. However, if as indicated above, the basal member of the Taraises is of Hauterivian age, and the San Paulo is of Tithonian age a stratigraphic interval equivalent to the Berriasian and Valanginian stages is apparently absent from the section, and the contact is therefore to be described as paraconformable.

Los Nogales Member.—The lower member of the Taraises Formation as exposed in the area of the present study was named the

Los Nogales Member by Piaggio in 1962 (unpublished M.S. thesis, Tulane University) who applied the term to a "sequence of alternating shales and limestones which crop out in the . . . eastern part of the Los Muertos anticline. . . . This unit lies with apparent conformity (actually paraconformably) above the calcareous sandstones of the [San Paulo Sandstone] and below the distinctive limestones of the upper member of the Taraises Formation. An excellent exposure of these strata in a small arroyo on the north flank of the Los Muertos anticline, approximately 750 yards west-southwest of La Cuchilla, is designated as the type locality."

"The Los Nogales Member ranges in thickness from 130 to 135 feet on the south flank of the anticline, and from 185 to 198 feet on the north flank. Obscure faulting in the thick mass of shale which makes up the middle part of the unit may be the cause of the thinning on the south flank."

The member is divisible into three lithologic units, a basal sequence of resistant, ridge-forming limestones, a middle unit of soft shales that form a topographic saddle behind the limestone ridge, and an upper zone of sandy limestones, dark gray on fresh surface, that weather a rusty brown color. The type section, as measured by Piaggio includes the following strata:

Unit		Feet
10.	Limestone, dark gray to black, weathering yellowish brown, sandy with subangular to subrounded quartz grains; contains irregular patches of bright orange siderite, some altered to limonite; fossiliferous, fauna includes terebratulid brachiopods, crinoid segments, belemnites, an olcostephanid and other ammonites, and numerous smaller mollusks. A one foot zone of greenish-brown fissile shale weathering yellowish-brown that contains pyritized (altered to limonite) echinoids and olcostephanid ammonites	5.5
9.	Shale, greenish-brown, weathering pale yellowish-brown, very fissile, with small silty limestone concretions that contain distorted echinoids. Unit becomes increasingly calcareous toward top where several medium-bedded (6 to 12 inch) dark-gray, silty, fossiliferous limestones that weather yellow-brown are intercalated	22
8.	Interbedded limestones and shales: limestone, dark-gray to black, weathers yellow-brown, medium-bedded (3 to 12 inches) becoming more evenly bedded and increasingly silty toward the top of the unit; fossiliferous, with terebratulid brachiopods, belemnites and some pelecypods; alternates with shale, fissile, brownish-gray, weathering tan. Limestone-shale ratio increases upwards with shale zones approximately 10 ft. thick at bottom and 2-3 ft. thick at top	38.5
7.	Shale, dark-gray to black, weathering brownish-gray, calcareous, very brittle and poorly fissile; near the top are several 4 to 8 inch beds of silty, dark-gray limestones that weather medium gray	53
6.	Shale, brownish-gray, weathering yellowish-brown, fissile, highly contorted with distinct slaty cleavage and well-developed pencil structure; at base a 6 inch bed of very silty, unevenly-bedded dark- gray limestone that weathers gray	30.5
5.	Shale, light-gray, weathering yellowish-white, calcareous, platy, marly; at base a 2 inch bed of light brown limonitic shale that weathers a bright yellow-brown which has been traced laterally for more than one-half mile on the north side of the Valle de San Paulo	8
4.	Shale, dark-gray to black, weathering yellowish-brown, calcareous, platy, poorly fissile; at base a 2 inch bed of crystalline white calcite with minute partings of non-calcareous black shale	13.5
3.	Marl, chalky-white, weathering a dirty-yellow, soft and powdery, with occasional thin beds of black limestone that weather gray; fossiliferous with	

Unit		Feet
	limonitic concretions containing echinoids, and echinoids and ammonites replaced by limonite	
2.	Limestone, dark-gray, weathering medium gray, very fine grained to sublithographic, dense, with numerous white calcite veins up to one inch thick transverse to the bedding; a thick (3′ 10″) bed at base, becoming increasingly thin-bedded upwards; abundantly fossiliferous with many ammonites (*Acanthodiscus, Distoloceras, Leopoldia, Neocomites, Thurmanniceras* (?), etc.), belemnites, pelecypods, occasional rhynchonellid and terebratulid brachiopods, crinoid segments, and rare corals	9
1.	Interbedded thin- to medium-bedded limestones and marls: limestones, similar to unit 2, with same fauna; marly interbeds, 2 to 7 inches thick. A 3 foot limestone bed at base	8.5
		198.5

In addition to the lesser thickness of the Los Nogales Member on the south flank of the Los Muertos anticline, measured sections reveal the following differences from those on the north flank of the structure: (1) the basal limestone sequence is slightly thicker, averaging 26 feet in thickness, and is most notably different in the almost complete absence of ammonites which are so conspicuously present on the north flank. These beds appear rather sparsely fossiliferous in outcrop with a fauna that includes belemnites, brachiopods, crinoid segments, rare corals and bryozoa. Thin sections, however, reveal that some of the beds contain abundant fragments of colonial cyclostome bryozoans and echinoid plates and spines. (2) The middle shale segment is thinner, 76 to 80 feet thick, but not greatly different, lithologically from that of the north flank. (3) The dark gray to black, brown weathering arenaceous and sideritic limestones with terebratulid bachiopods and other fossils, are in general thinner-bedded and have thicker shale units (up to 4 feet thick) intercalated between them. As a result the upper sequence is thicker, measuring up to 27 feet in some sections, although the total amount of limestone is not greatly different from that on the north flank.

Upper Member, Taraises Formation.—The upper member of the Taraises Formation consists of a rather monotonous sequence of black, fine-grained, dense limestones that weather to a light gray color and usually break down to shale-like slopes. As a result the inter-valley ridges appear to be underlain by a sequence of shales, whereas the fresh exposures in the valleys reveal the calcareous nature of the member. Some of the beds yield a strong fetid odor when struck with a hammer; a sample of such material dissolved in acid left a minor sludge of carbonaceous material and minute crystals of pyrite. The whole is suggestive of deposition under euxenic conditions. Some bedding planes, however, bear fucoidal impressions suggestive of a bottom fauna, and a few fossils, including ammonites and pelecypods occur, though not uniformly distributed throughout the section. A unit some five feet thick, located approximately 60 feet below the top of the formation has yielded numerous specimens of a gigantic species of *Harpagodes* (?). Hence it is evident that, if the depositional environment was occasionally euxenic, such conditions did not persist throughout the entire time interval encompassed within the member. The *Harpagodes* (?) zone has been recognized in all sections where the interval of its occurrence is exposed, and it constitutes a useful stratigraphic marker in this region.

A section measured on the north flank of the anticline by James A. Holliday follows; it was measured along a small draw immediately above an abandoned swimming pool that is located to the east of the saddle formed on the shales of the Los Nogales Member above the collapse block of Cupido Limestone adjacent to the type section of the San Paulo Formation:

Unit		Feet
9.	Limestone, dark grayish black, weathering medium light gray, obscurely cross-bedded, weathers to shaly slope; rocks yield strong fetid odor when struck	65
8.	Limestone, dark grayish black, weathers medium light gray, in 1 to 2 foot beds; fossiliferous with many specimens of *Harpagodes* (?) sp.	5
7.	Limestone, similar to unit 9,	

Unit		Feet
	gray black, weathering brownish gray with rough sandy surface; beds 4 to 5 feet thick; some highly fossiliferous beds in interval 20 to 55 feet below top	33
6.	Limestone, medium-bedded to massive, with thin shaly interbeds; limestone weathers to shaly slopes	565
5.	Shale, gray black, weathering brownish gray, calcareous	0.5
4.	Limestone, gray black, weathering light gray; contains a few pelecypods and ammonites that have been limonitized and are poorly preserved	1
3.	Shale, similar to unit 5	1.5
2.	Limestone, similar to unit 9, medium- to thick-bedded	51
1.	Limestone, similar to unit 2, but with much pyrite that weathers to limonitic stains	30
		752

A section measured on the south flank of the anticline, on the west side of a large tributary canyon approximately one and three-quarters miles west of Cañon de Morteros by R. F. Beyer, Jr., V. V. Cavaroc, Jr., and G. C. Glaser, well illustrates the lithologic consistency of the member:

Unit		Feet
4.	Limestone, dark gray to black, weathering light gray, dense, thick- to massive-bedded, emits a fetid odor when struck; rock weathers along joints and bedding planes to develop a resistant "blocky" surface residue	74
3.	Limestone, dark gray, weathers grayish-white, thick-bedded, fossiliferous, with numerous large *Harpagodes* (?) sp.	10
2.	Limestone, dark gray, weathering medium gray, weathers to a shaly slope; rock is medium-bedded below and becomes thicker bedded toward the top; thin shale interbeds. Some beds sparsely fossiliferous	152
1.	Limestone, light to dark gray, argillaceous, dense, weathers light gray to brownish buff in color forming fragments simulating a shale; basal beds of more pure limestone, more resistant and marked by limonitic stains	456
		692

Nuevo Leon Stage

Cupido Limestone

The Cupido Limestone, named by Imlay (1937, p. 606) for 1,415 feet of thick-bedded gray limestone exposed in the middle part of the Sierra de Parras, is the major ridge-forming formation in southeastern Nuevo Leon and adjacent areas of Coahuila. It crops out as strike ridges forming the north and south walls of both the Valle de San Paulo and the Valle de Muralla. Both the Cañon de Huasteca on the north and Cañon de Morteros on the south of the map area are cut through these strike ridges.

The formation is composed of thin- to thick-bedded and massive limestones, light brown to light gray, dark gray and black in color, and rudistid-bearing. Stylolitic suturing of the bedding planes is commonly present. Humphrey (1949, p. 102) states that in the western part of the Sierra de Los Muertos "the base is everywhere marked by a thick-bedded unit of dolomite and dolomitic limestones." In the area here under study the basal beds are all non-dolomitic limestones. There are, however, some dolomitic limestones and one or two beds of dolostone toward the middle part of the sequence.

The contact of the Cupido Limestone with the underlying Taraises Formation is conformable and is here drawn where the limestone becomes thick-bedded, resistant and cliff-forming.

Although the section in the Cañon de la Huasteca is perhaps more spectacularly exhibited, and is certainly better known to geologists and visitors, that in the Cañon de Morteros to the south is more completely exposed. A section measured mainly along the eastern wall of this canyon, with the basal beds being measured on the western wall, follows. The measurements were made by Anthony T. L'Orsa in 1961:

Unit		Feet
19.	Talus and caliche covered	6
18.	Limestone, medium to dark gray, weathering medium gray, thin- to very thick-bedded; upper foot thinly laminated; occasional rudistid pelecypods	20

Unit		Feet
17.	Limestone breccia, light to dark gray, weathering medium dark gray; appears to be intraformational breccia with slabs up to four feet long	3
16.	Limestone, medium gray to black, weathering medium to dark gray, with a few interstratified light gray beds; some rusty weathering, nodular, gray chert; rudistid bearing; stylolite columns up to one foot in length	204
15.	Limestone, dark gray, weathering medium gray, finely crystalline crowded with monopleurid (?) rudistids that have been recrystallized to white calcite. This rock has been locally "quarried" for terrazzo stone	7
14.	Limestone, medium to dark gray, weathering light to medium gray, thick-bedded, stylolitic; some fractures contain small quartz crystals embedded in calcite fracture fillings and small vugs; moderately fossiliferous with a rudistid fauna	255
13.	Limestone, medium gray to light brownish gray, weathers medium to light brownish gray, thick- to very thick-bedded, stylolitic with columns up to 8 in. long; rudistids moderately abundant	181
12.	Limestone, dolomitic, medium gray, weathering medium gray with a rough sugary textured surface. Rock is more coarsely crystalline than adjacent limestones	16
11.	Limestone, light to medium brownish gray with the lighter and darker layers alternating; weathering color corresponds approximately to color of fresh surface; medium to very thick-bedded; lighter colored beds tend to be sublithographic in texture, and more fossiliferous than the darker; fauna mainly rudistid but some *Nerinea* were noted	598.5
10.	Dolostone, medium gray, weathering brownish gray, sugary in texture	2.5
9.	Limestone, light brownish gray to dark gray with colors alternating every few feet; weathers in light to dark brownish gray bands with medium brownish gray predominating; a few isolated strata are dolomitic; thick- to very thick-bedded; sparsely fossiliferous	606
8.	Limestone, light brownish to light olive gray, weathering light gray, fine crystalline; thick- to very thick-bedded; fauna includes rudistids and large *Nerinea*	68
7.	Limestone, medium to dark gray, weathering medium gray, thick- to very thick-bedded; some beds crowded with rudistids, others sparsely fossiliferous; a single coral was observed	268
6.	Covered interval, a single limestone bed two feet thick exposed near center, medium gray, weathering lighter gray, with abundant rudistids	52
5.	Limestone, argillaceous, thinly laminated, medium gray, weathering medium gray to fissile-like fragments	3
4.	Limestone, grayish black, weathering dark gray, thick-bedded, stylolitic	14
3.	Limestone, argillaceous, with thin uneven laminations, light to dark gray and brownish gray, weathering same; interbedded with a lesser amount of thick-bedded limestone, non-argillaceous, dark gray weathering medium gray	35
2.	Talus covered interval	15
1.	Limestone, dark gray, weathering medium gray, thick-bedded, stylolitic	26
		2,380

Comanche Series
Trinity Stage
La Peña Formation

Imlay proposed the term La Peña Formation in 1936 (p. 1119) for the "lower and middle portions of the mountain-forming limestones, as exposed in the Sierra de Parras, lying stratigraphically between the Parritas formation (below) and the Aurora limestone (above)." Two members were recognized, a lower consisting of "about

1400 feet of light- to dark-gray, thick- to medium-bedded limestones, which include some shaly partings," and an upper member ranging from 50 to 80 feet in thickness which "consists of thin-bedded limestones and shales." A measured section of the lower member in Cañon Platanos south of Parras, included 2190 feet of limestones with minor shale.

In 1937 (p. 606) he proposed the name Cupido Formation for "thick-, medium-, and thin-bedded limestones above the Taraises formation and below La Peña formation" but continued to include a thick limestone sequence as the basal member of the overlying La Peña the contact being "drawn where thin-bedded and platy limestones become abundant." The distinction between the two limestone units is not apparent in the sections exposed in the Nuevo Leon area, the limestones being medium- to thick-bedded throughout the entire sequence. The writer follows Humphrey (1949, p. 103) in applying the name Cupido Limestone to the entire sequence while recognizing that the upper portion probably corresponds in stratigraphic position to the lower member of Imlay's original La Peña Formation. The latter name is thus restricted to a sequence of marls and shaly limestones with one or two more resistant limestone strata that are the stratigraphic equivalent of the upper member of Imlay's La Peña. These beds, which are abundantly fossiliferous with a rich ammonite fauna of upper Aptian age, are much less resistant than the adjacent massive limestones of the Cupido and Aurora formations and weather to a narrow strike valley whose surface is strewn with talus to the point that outcrops are rare and difficult to locate.

No section adequately exposed for measurement has been located in the present mapped area, but a partial section exposing the lower beds of the formation is well shown adjacent to a shaft sunk by the Comisión Agua Potable de Monterrey. The section penetrated in this project was slightly in excess of 15 meters thick (oral communication). The portion exposed includes the following units:

Unit		Feet
4.	Limestone, dark gray weathers medium gray, in beds about 1 foot thick, dense, argillaceous; moderately fossiliferous with fauna including ammonites, belemnites, echinoids and rare pelecypods	10
3.	Shale, medium light gray, weathers light gray, very marly; fauna includes echinoids, belemnites and occasional ammonites	1.5
2.	Limestone, medium dark gray, weathering a grayish yellow-brown, very nodular and unevenly bedded with interbeds of gray marly shale; highly fossiliferous, with abundant ammonoids that include almost all species described by Humphrey (1949), together with nautiloids, belemnoids, rare pelecypods, gastropods, and echinoids; fossils characteristically red-colored on surface	8
1.	Limestone, dark gray, weathering brownish gray, thin- to medium-bedded, very argillaceous, with thin interbeds of marly gray shale; fossiliferous, fauna including *Plicatula* sp., *Astarte* (s.l.) and other pelecypods together with rare brachiopods	5
	exposed thickness	24.5

On the north side of the anticline there is a characteristic erosional notch on the east wall of the Cañon de la Huasteca near the entrance of the canyon. Unfortunately, however, the strata here are covered with talus from the adjoining Cupido and Aurora limestones and no section can be studied. On the west side of the canyon, immediately above the end of the paved road from Santa Catarina, a few fossils, collected from the saddle at the crest of the ridge are sufficient to establish the presence of La Peña at this position in the structure.

The contact with the underlying Cupido Limestone is concordant and sharp, the uppermost Cupido strata forming a distinct wall adjacent to the basal La Peña strata. Present knowledge of the faunas of the upper part of the Cupido Limestone is insufficient to permit any conclusions as to whether the sharp lithologic change between the two formations is simply a change in deposition regime or is indicative of a time lapse between them.

Trinity (?) and Fredericksburg Stages

Aurora Limestone

The Aurora Limestone, named by Burrows (1910, pp. 96-97) for 600 to 1500 feet of cherty limestones in the Sierra de La Aldea in northeastern Chihuahua, is, like the Cupido Limestone, an important mountain-forming unit. In the area of the present study it crops out at the northern entrance to the Cañon de la Huasteca, forming the front of the first ridge of the Sierra Madre Oriental, and on the southern flank of the Los Muertos structure it occurs at the southern entrance to the Cañon de Morteros to form the north wall of the broad synclinal valley south of the Valle de San Paulo-Valle de Muralla area. Only the basal beds are exposed in both outcrop belts. Fresh surfaces of the limestone are dark gray to grayish black in color and weather a medium gray in color. The beds are medium to very thick, or massive, and characteristically contain brownish-weathering black chert in irregularly shaped nodules and concretions. Stylolitic suturing of bedding surfaces is generally to be observed and rudistids are not rare in some of the strata, though absent in others.

Tertiary (?) or Quaternary System

"enigma clay"

The informal designation, "enigma clay," has been applied in the field to a small deposit located immediately southwest of the schoolhouse in the *población* of Los Nogales. The deposit consists of approximately 60 feet of thin-bedded, calcareous clay in thin beds, one to three inches thick, that are more or less alternately light grayish yellow and orange buff in color. The deposit rests upon a water-worn eroded surface of the upper member of the Taraises Formation, with, in the small area where the floor is exposed, no trace of a basal sandy, or conglomeratic, layer. The Taraises has a strike of N. 65° W. and dips 85° to the south; the clays strike N. 40° E. with dips varying between 23° and 31° S. Overlying the clays is a coarse bouldery alluvium containing large blocks of the Cupido Limestone.

In the laboratory, samples of the clay prove to contain twenty-five percent $CaCO_3$ (by weight), gave a positive test with benzidine, and after the lime had been leached out all the residue passed a 200-mesh screen. There was no trace of swelling, although the leached sample, after drying, disaggregated in water.

The origin of the clay deposit is not clearly understood. The thin, even bedding, clearly indicates subaequeous deposition, and the fineness of the material strongly implies relatively quiet waters; hence a lacustrine origin is suggested. Nevertheless, it is difficult to explain the absence of any coarser debris, especially since the deposit lies on the Taraises Formation at a point less than 400 feet from high-standing, resistant, cliff-forming strata of the Cupido Limestone. Careful examination along the entire face of the quarried area has failed to reveal even a single pebble of limestone. Furthermore, there are no traces of organic material, save for rootlets of plants that have penetrated into the deposit from above, and it is to be expected that a lake in this general region would contain some traces of leaves, or wood, and especially should have had a molluscan fauna that would have left occasional shells in the bottom sediment.

It has been suggested that the absence of coarse material might be explained if we assume that the adjacent Cupido cliffs were beneath the waters of the lake. This would require a water depth of 800 to 1000 feet and, in the general regional topographic setting now indicated, would have resulted in a lake many hundreds of square miles in area. In the light of so large a body of water it is difficult to explain the absence of any evidences of its existence other than the one small clay deposit now known.

Quaternary System

Alluvial Deposits

Extensive alluvium and colluvium covers the floors of both the Valle de San Paulo and the Valle de Muralla, and alluvium is present in both the Cañon de la Huasteca and the Cañon de Morteros. These materials include, in addition to normal valley channel and flood plain deposits, a veneer of caliche-cemented piedmont debris covering the lower slopes of the ridges that margin the valleys. For some reason not yet understood the caliche-cemented deposits appear to be more extensively developed in the Valle de Muralla, especially toward the western end where they occur at elevations as much as 600 feet

above the present valley floor, reaching altitudes of almost 3,100 feet above sea level. In the Valle de San Paulo they seldom occur more than 200 feet above the valley floor.

Over most of the area the caliche-cemented deposit is sharply delimited from the valley alluvium, and the former is interpreted as the product of a depositional period characterized by a more pluvial climate than that presently existing in the region.

V. Structural Features

The Cañon de la Huasteca area lies within the broad regional structure known as the Los Muertos anticline, the prominent fold whose northern limb forms the front of the Sierra Madre Oriental in the immediate vicinity of Monterrey and westward into the eastern part of the State of Coahuila. Within the area studied the anticline is asymmetrical with the strata on the north flank dipping 80 to 90 degrees or overturned, and those on the south flank, in general, dipping less steeply. There is, however, variation in the attitude of the beds. The steepest dips recorded are in the general vicinity of the Cañon de la Huasteca on the north flank, and of the Cañon de Morteros on the south. On the north flank of the structure, within the Valle de San Paulo there is a progressive reduction in the dip angle westward from the Huasteca, until, near the western edge of the mapped area the dips are mainly in the range of 50 to 60 degrees. Outside of the Valle de San Paulo, on the northern side of the Cupido-Aurora Limestone ridge, there is a reversal of this situation, with the ridge-forming limestones becoming more and more overturned westward from the Cañon de la Huasteca until, as may be observed from the Monterrey-Saltillo Highway, the dips in the upper portions of the ridge are approximately 60 degrees to the south.

On the south flank of the anticline in the Valle de San Paulo the Cupido and Taraises formations have dips of 84 to 85 degrees to the south at stream level, but the arching of the strata into the anticlinal structure is revealed in dips as low as 70 degrees on the higher ridge elevations. Less than a mile to the west, however, dips of 36 and 38 degrees are recorded in the San Paulo Sandstone and the Los Nogales member of the Taraises Formation. From this point westward, in contrast to the situation observed in the northern part of the valley, there is a gradual increase in the angle until 60 degree dips are recorded toward the western terminus of the mapped area.

An apparent fault near the axis of the anticline also complicates the interpretation of the Los Muertos structure in the Valle de San Paulo area. This fault is nowhere visible, its trace apparently lying below the alluviated valley of the intermittent stream which flows along the south side of the Zuloaga morros that mark the anticlinal crest. The presence of the fault is inferred primarily from the insufficient room between the outcrops of the Zuloaga Limestone and the San Paulo Sandstone on the south limb of the anticline for a thickness of Muralla Shale equivalent to that measured on the north flank of the structure (see Fig. 2). Other evidence is that the few dips which could be obtained in the Zuloaga Limestone in the Valle de San Paulo section are all steeply overturned, but the San Paulo Sandstone on the south limb of the structure (and less than one thousand feet from the Zuloaga) dips from 36 to 59 degrees to the south. Finally, just beyond the western end of the mapped area on the southern margin of a Zuloaga morro the dark gray limestone is completely brecciated into fragments "floating" in a matrix of white crystalline calcite. The limestone fragments, only a few inches in greatest length, are separated by from one to four inches of calcite.

It is of interest to note, in this connection that, although Böse had earlier (1923, p. 129) commented that "one of the most astonishing features of the region is the absence of faults and overthrusts," he recognized the probable existence of the present fault which he shows in a small cross-section (p. 200) and he states (p. 324): "Along the middle of the valley probably lies a fault of small importance; toward the south the Oxfordian [Zuloaga] limestone seems to break off where the beds should begin to dip toward the south."

Some evidence as to the nature of the fault may be gained from a study of the well developed axial-plane cleavage or fan-jointing which strikes parallel to all of the observable regional structures. A compilation of the dip pattern of this cleavage was made by V. V. Cavaroc, Jr., of the 1961 field group. This revealed that the projections of

the cleavage dips measured on the south flank of the anticline converged at a point northward from the convergence point of those measured on the north flank, and also somewhat deeper below the surface. Mr. Cavaroc concluded (unpublished field report): "While the number of fan dips taken [were not sufficient to permit a positive statement], the results are consistent enough to strongly indicate a major, low angle, axial thrust fault dipping about 25° northward." The amount of displacement would be in the magnitude of 800 to 1,200 feet, depending upon whether or not a portion of the Zuloaga Limestone on the south limb of the fold was also displaced as suggested by Böse.

There is general agreement that the forces which deformed the Jurassic and Cretaceous sediments into the folds now represented in the Coahuila-Nuevo Leon portion of the Sierra Madre Oriental of Mexico were derived from the south-southwest (Böse, 1923, p. 333; Humphrey, 1949, p. 113; 1956, p. 28; De Cserna, 1956, p. 69; etc.), and this is well shown in the Cañon de la Huasteca area by the steepened north dips and overturning on the northern flank of the Los Muertos anticline as compared with the gentler dips on the southern flank. But this same consideration implies that the fault movement occurred as an underthrust movement from the south to the north. It also has been generally agreed that one cause of the strong overfolding to the north is that the sediments folded were caught between the forces from the south-southwest and the margins of a now buried block of Paleozoic and early Mesozoic sediments and associated igneous rocks that was positive in late Jurassic time (and was the source of the clastics represented in the Muralla Shale and, especially, in the San Paulo Sandstone). This block represents the "Ancient Continent" of Böse (1923) and Burckhardt (1930-31) and the Coahuila and Tamaulipas peninsulas of Kellum, Imlay and Kane (1936), Imlay (1943) and of subsequent authors.

It is somewhat difficult for the present writer to visualize underthrusting in the present region which should be situated rather near the margins of the hypothecated positive block, unless some special conditions occurred. These may be found in the presence of the gypsum in the region, as evidenced by the intruded gypsum noted in the Zuloaga Limestone in the Valle de San Paulo area, and in the Sierra del Fraile to the northwest. It is here suggested that the gypsum intrusions in the Valle de San Paulo area may have been one result of the faulting in this valley, and it might even be possible that the underthrust mass, moving into a series of strata of gypsum and anhydrite would act more or less like a plunger being forced into a cylinder of liquid, to displace the evaporites and to force their movement, perhaps in part along the fault plane, and especially along the bedding-planes between the massive limestone layers of the Zuloaga. It thus may be significant that the only occurrences of intrusive gypsum in the region coincide rather precisely with the limits of the area in which the evidence for faulting noted above are to be observed.

The anomalous structural features are not continued laterally into the Valle de Muralla to the east of the valley of the Rio Santa Catarina and there is no evidence to suggest the presence of a fault at the crest of the anticline in this region. Dips are relatively steep on both flanks, although somewhat more steep on the north than the south.

Cross faults, or tear faults, noted by Humphrey (1949, pp. 114-5) on the north flank of the anticline in the region to the west of the present area have not been observed during the course of the present study. There is, on the other hand, an apparent slight southerly offset of the formations in the core region of the anticline on the east side of the valley of the Rio Santa Catarina as compared with those on the left. Furthermore the fact that the caliche-cemented alluvial deposits occur at much higher slope elevations in the Valle de Muralla than they do in the Valle de San Paulo, and the much broader outcrop width of the Zuloaga Limestone belt in the Valle de Muralla, all tend to suggest the presence of a small cross fault near the present course of the Rio Santa Catarina, and also to indicate that the east side was uplifted with respect to the west. On the other hand, the fault either did not affect the Cañon de Morteros on the southern flank, or else the movement was strictly parallel with the direction of dip, for one can easily observe the continuation of the individual strata directly opposite each other in the canyon walls. The rather sinuous course of the Cañon de la Huasteca makes

it a bit more difficult to check the individual beds on the opposite walls, but they appear to be continuous across the structure, and there is no striking difference in dip on the two sides as was reported by Humphrey from the area near Las Cortinas canyon (1949, p. 115).

Collapse structures.—Incidental mention has been made of a ridge north of the second Zuloaga morro west of the Rio Santa Catarina that is capped by a large collapse mass of Cupido Limestone resting on the upturned edges of the San Paulo Sandstone. This limestone mass cannot be interpreted as an example of rock fall or talus because, although now somewhat broken up by undercutting resulting from the weathering of the softer San Paulo strata around the margins of the mass, the material obviously reached its present position without notable disruption. The mass is here interpreted as representing a form of "slip-sheet," defined by Harrison and Falcon, (1934; 1936) as "a slab of rock which has become detached from its original place on a dip-slope and has slipped down, remaining more or less intact" (1936, p. 92). In the present instance, however, the slab has slipped down on the inner side of the fold, rather than down a dip-slope, apparently because the differential erosion of the softer Taraises sediments and the highly resistant Cupido limestones left an almost vertical block of the latter without adequate buttressing. It seems that the block must have been weakened below, either by erosion or because of excessive joint or fracturing at the base, and thus have slid as a unit, rather than have toppled over from above, since the latter assuredly would have resulted in the free fall of a major portion of the mass, disrupting it to form rock-fall debris.

There is a second, well-exposed, and apparently more recently formed example of a collapse structure exhibited on the north wall of the synclinal canyon immediately to the south of the mapped area. It is located four to five miles east of the southern terminus of the Cañon de Morteros. Determination as to whether it represents a "flap" or a "slip-sheet" must await careful examination of the strata involved.

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A NEW SPECIES OF FORAMINIFERIDA FROM THE MIOCENE OF SOUTH LOUISIANA

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Abstract

A new species of nodosarine Foraminiferida is described and illustrated. *Lenticulina (Robulus) cristi,* sp. nov., is an important stratigraphic marker which occurs above *Cibicides carstensi opima* Cushman and Ellisor and below *Bigenerina humblei* Cushman and Ellisor in the middle Miocene of South Louisiana.

Stratigraphic marker fossils in the subsurface of South Louisiana are essential to comprehension of the complex stratigraphy and, in fact, provide the means of establishing regional correlations in the area. The middle Miocene sediments form a prolific producing trend of great interest to Gulf Coast geologists. The purpose of this note is to describe and illustrate one of the foraminiferal species characteristic of this interval which has not been formally named. This form, commonly referred to as "*Cristellaria* I", occurs most prominently above *Cibicides carstensi opima* Cushman and Ellisor and below *Bigenerina humblei* Cushman and Ellisor in the neritic sediments of the middle Miocene of South Louisiana. It is one of the more prominent species in the "Krumbhaar fauna" which is considered reliable for regional correlation.

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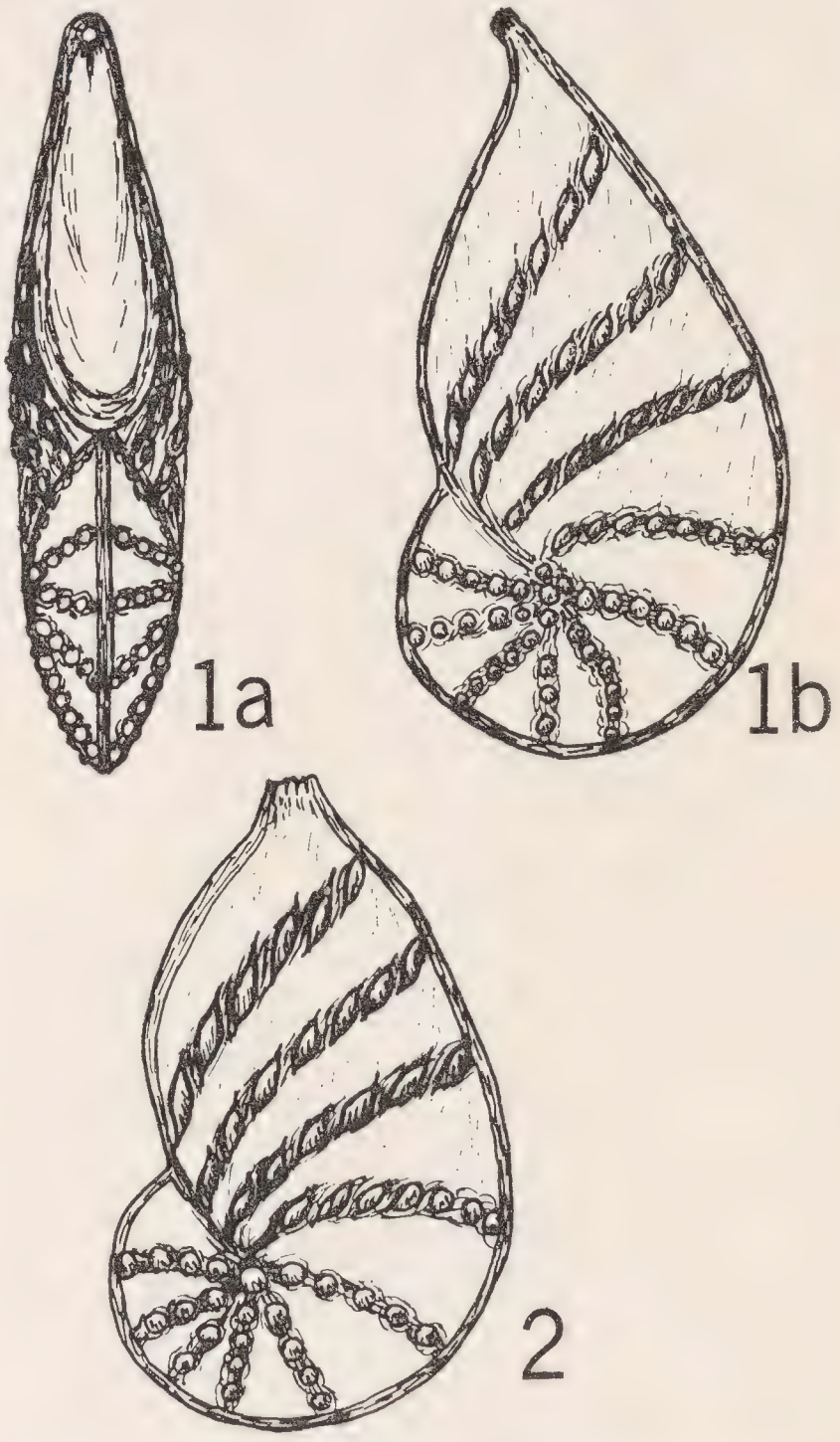
Systematic Description

Order Foraminiferida Zborzewski, 1834

Superfamily Nodosariacea Ehrenberg, 1839

Family Nodosariidae Ehrenberg, 1839

Subfamily Nodosariinae Ehrenberg, 1839



Lenticulina (Robulus) cristi Skinner, sp. nov. (X50) : Fig. 1a, b, USNM 640982 (holotype) ; Fig. 2, TGC 5-1 (paratype).

Genus Lenticulina Lamarck, 1804

Lenticulina Lamarck, 1804, Mus. Natl. d'Hist. Nat., Ann., vol. 5, p. 186

Subgenus Robulus Montfort, 1808

Robulus Montfort, 1808, Conch. Syst., vol. 1, p. 215, 54th genre

Type species: Robulus cultratus Denys de Montfort, 1808. Original designation. *Gender:* masculine.

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LENTICULINA (ROBULUS) CRISTI
Skinner, sp. nov.
Figs. 1a, 1b, 2

Diagnosis: Test planispiral, compressed, involute, almost becoming uncoiled in the adult stage; periphery angled, indistinctly carinate; chambers distinct, 9 to 12 in the last volution; sutures limbate, bearing a series of sharply distinct, raised beads which are rounded in the coiled juvenarium but are somewhat elongated subparallel to the dorsal periphery in the adult portion of the test; wall calcareous, perforate; surface smooth and flush except for the beaded ornamentation; aperture elevated, radiate, distinctly robuline with an elongated slit in the median line extending into the apertural face.

Figured specimens: Fig. 1, USNM 640982 (holotype), length 1.08 mm, breadth 0.58 mm, thickness 0.29 mm; and Fig. 2, TGC 5-1 (paratype), length 1.05 mm (aperture broken), breadth 0.58 mm, from cuttings at 10,636 feet in the Frankel #1 Clotilda (WC), sec. 12, T. 16 S., R. 19 E., Lafourche Parish, Louisiana. Age: middle Miocene.

Unfigured paratypes: TGC 5-2 and 5-3 from cuttings at 12,420 feet in the Sunray #1 State Lease 3487, Iberia Parish, Louisiana.

Discussion: This common form is easily recognized by the incised or "slashed" appearance of the spaces between the sigmoid beads on the adult sutures. Some more robust specimens have a thicker shell and more prominent nodes (TGC 5-2) than the holotype, but though atypical are considered conspecific.

The associated fauna includes *Gyroidina scalata* Garrett and *Ellipsonodosaria verneuili emaciata* Palmer and Bermudez.

Lenticulina (*Robulus*) *vaughani* (Cushman) described from the Miocene of the Canal Zone is similar but does not have the sigmoid or elongated nodes on the adult sutures, which are distinctive of *L.* (*R.*) *cristi.*

Occurrence: Lenticulina (*Robulus*) *cristi* and the associated fauna are encountered south of a line extending from southeastern Vermilion Parish through southern Iberia, southern St. Mary and St. Martin, southern Assumption, northern Lafourche, and southern St. Charles parishes to central Jefferson Parish. Eastward this species is encountered in younger sediments and becomes unreliable. The fauna is considered to be typically developed in Lafourche and Terrebonne parishes.

TULANE STUDIES IN GEOLOGY
Vol. 1, No. 4, August 22, 1963

NOTES ON CENOZOIC MURICIDAE FROM THE WESTERN ATLANTIC REGION, WITH DESCRIPTIONS OF NEW TAXA

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TULANE UNIVERSITY

I. Abstract

Nine new species-groups assigned to the subfamilies Muricinae and Tritonaliinae are described and one new subgenus *Miocenebra* (Tritonaliinae) is proposed. Two additional species are refigured and reassigned.

II. Introduction

Extensive collecting from the Tertiary formations of the Atlantic and Gulf Coastal Plain by the Tulane Geology Department has yielded a number of new species of Muricidae, as well as providing material which enables the writer to revise the generic (or subgeneric) placement of others. The author has undertaken the project of monographing the Muricidae, and these new species or reassignments are here presented in order to avoid introducing new taxonomic units in the final work. In this paper nine new species-groups and one new subgenus are described. Two additional species are assigned to different supraspecific groups, and are refigured with better specimens. The taxa here presented, with their geologic position, are:

Murex (Bolinus) vaughani Maury ——— Lower Miocene
Murex (Chicoreus) lepidotus, n. sp. ——— Lower Miocene
Murex (Chicoreus) lepidotus dujardinoides, n. subsp. ——— Lower Miocene
Murex (Phyllonotus) dormani, n. sp. ——— Middle Oligocene
Murex (Phyllonotus) infrequens, n. sp. ——— Lower Miocene
Murex (Phyllonotus) riparius, n. sp. ——— Upper Miocene
Murex (Murexiella) macgintyi facetus, n. subsp. ——— ?Lower to Upper Miocene
Murex (Panamurex) gilletteorum, n. sp. ——— Lower Miocene
Murex (Panamurex) clarksvillensis (Mansfield) ——— Upper Miocene
Tritonalia (Tritonalia) festivoidea, n. sp. ——— Lower Miocene
Tritonalia (Miocenebra), n. subgenus ——— Miocene
Tritonalia (Miocenebra) silverdalense, n. sp. ——— Lower Miocene

III. Systematic Descriptions

Family Muricidae

Subfamily Muricinae

Genus Murex Linné, 1758

Subgenus Bolinus Pusch, 1837

Type species: *Murex brandaris* Linné, by original designation.

Murex (Bolinus) vaughani Maury

Plate 1, figs. 1a, 1b.

Murex vaughani Maury, 1910, Bull. Amer. Paleontology, v. 4, no. 21, p. 143, pl. 23, fig. 6.

Murex (Murex) vaughani Maury. Gardner, 1947, U.S.G.S. Prof. Paper 142-H, p. 519.

Murex (Murex?) vaughani Maury. E. H. Vokes, 1963, Tulane Stud. Geol., v. 1, no. 3, p. 102, pl. 1, figs. 2a, 2b.

Figured specimen: USNM 644370; height, 29 mm; diameter, 17 mm. Locality: TU 547, Chipola River (SW ¼ Sec. 29, T1N, R9W), Calhoun County, Florida.

Horizon: Chipola Formation, uppermost lower Miocene.

Discussion: In a recent discussion (1963) of this species the writer referred the species provisionally to *Murex* s.s., feeling that it was misplaced, but unable to make a better assignment. At that time there existed, so far as is known, only the type specimen at the Paleontological Research Institution, and one incomplete specimen in the Tulane

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collections. Since that writing another specimen has been collected (TU locality 547) which is the best yet found. This third specimen confirms the previous impression that the species correctly belongs to the subgenus *Bolinus.* It has the thin flaring inductura of that group and completely conforms in all other respects. In addition to the complete specimen, a fragment was also found consisting only of the siphonal canal. This fragment indicates a height of over 60 mm and is ornamented with three rows of long spines similar to *Murex cornutus* Linné or *M. tumulosus* Sowerby, both of which live today off West Africa. Except for lacking the long spines on the body whorl, *M. vaughani* bears a most striking resemblance to these two species and the possibility is immediately presented that this American species is perhaps ancestral to the *Bolinus* stock. *Murex torularius* Lamarck, the European ancestor of *M. brandaris,* the type of *Bolinus,* first appears in the middle Miocene (Helvetian) of France, Spain, Italy, and North Africa (Dollfus, 1926, p. 95) and it is not unlike *M. vaughani.* As the Chipola Formation is considered to be slightly older than Helvetian (Cooke, *et al.,* 1943) it is not impossible that the true origin of the line is in the New World. However, *M. vaughani* has no known American ancestors or descendants so it is more likely that this species made its way across the Atlantic Ocean from an Afro-European site of origin.

The ornamentation of *M. vaughani* is similar to *Murex (Panamurex) gilletteorum,* n. sp., of somewhat older age from the Silverdale beds of North Carolina. The two forms differ so greatly in all other respects, however, that it is not thought they are directly related. It is more probable that the similarity of ornamentation represents convergence.

Subgenus CHICOREUS Montfort, 1810.
Type species: *Murex ramosus* Linné, by original designation.

MUREX (CHICOREUS) LEPIDOTUS
E. H. Vokes, n. sp.
Plate 1, figs. 2a, 2b.

Shell large in size, whorls convex. Nucleus of two smooth, slightly bulbous whorls; termination of nuclear whorls marked by abrupt initiation of ornamentation. Seven post-nuclear whorls in the adult, suture appressed. Axial sculpture consists of ten equal nodes on the early whorls; on the third and successive post-nuclear whorls certain of these are strengthened to form four varices, with a single intervarical node between each pair. Spiral sculpture consists of primary threads, three in number on the earliest whorls, increasing to approximately six on the body whorl, with three additional primary threads on the pillar. Intercalated between the primary threads are one secondary, and usually two tertiary threadlets. Entire surface of shell sculptured by minute laminar incrementals which give a shagreened appearance to the intervarical areas. The free edges of the varices are

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PLATE I

		Page
1a, 1b.	*Murex (Bolinus) vaughani* Maury (X 2) USNM 644370; height 29 mm, diameter 17 mm. Locality: TU 547. Chipola Formation.	151
2a, 2b.	*Murex (Chicoreus) lepidotus,* n. sp. (X 2) USNM 644371 (holotype); height 34 mm, diameter 20 mm. Locality: TU 554. Chipola Formation.	152
3a, 3b.	*Murex (Chicoreus) lepidotus dujardinoides,* n. subsp. (X 2) USNM 644372 (holotype); height 32.5 mm, diameter 18.5 mm. Locality: TU 547. Chipola Formation.	155
4a, 4b.	*Murex (Phyllonotus) infrequens,* n. sp. (X 2) USNM 644374 (holotype); height 36 mm, diameter 19 mm. Locality: TU 458. Chipola Formation.	156
5a, 5b.	*Murex (Phyllonotus) riparius,* n. sp. (X 2) USNM 644375 (holotype); height 22.5 mm, diameter 12 mm. Locality: TU 60. Choctawhatchee Formation.	157

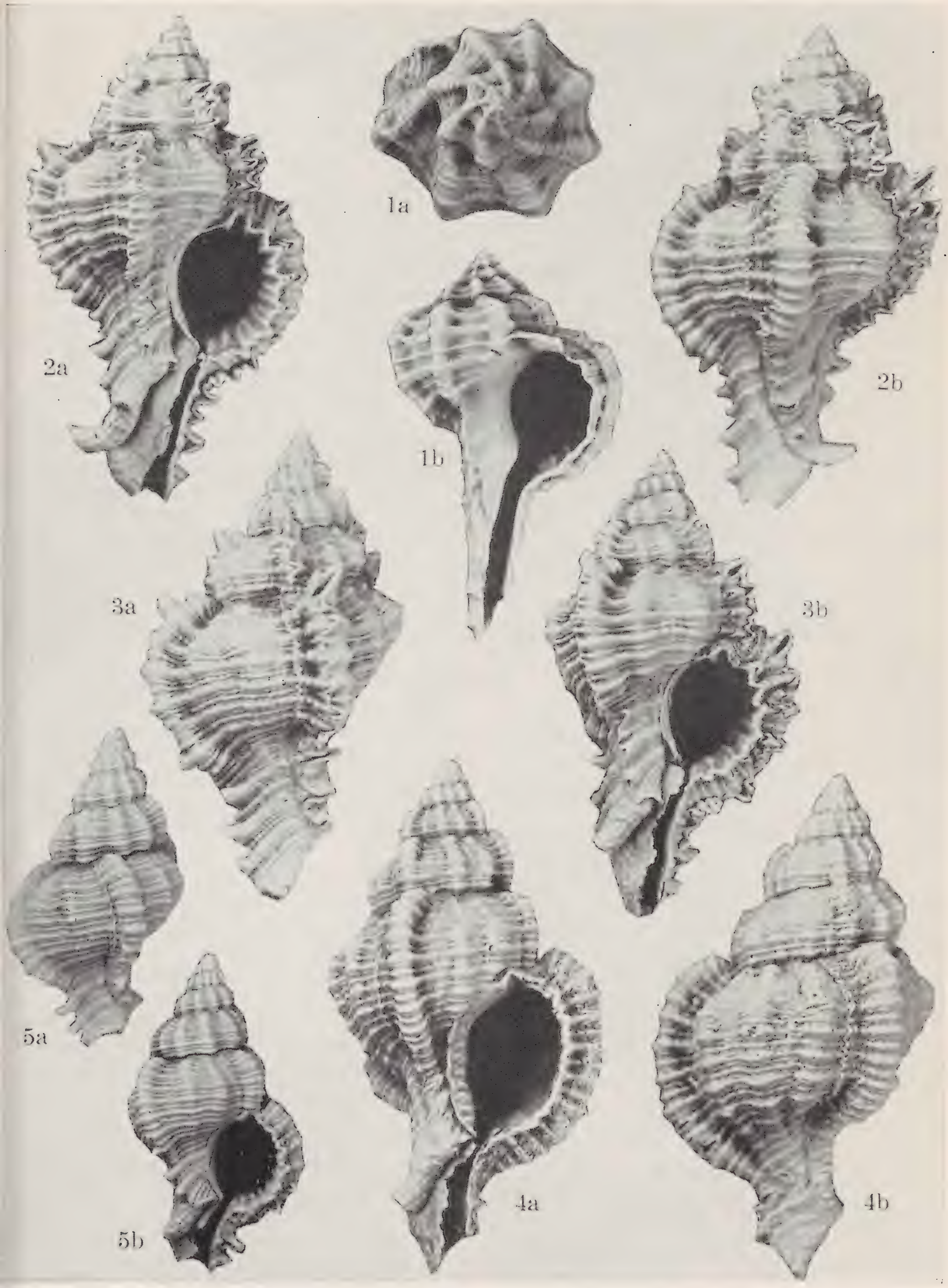

PLATE I

sharply fluted by a succession of laminae with small open spinelets produced where the primary threads cross the varices. Two series of slightly larger spines are developed on the siphonal canal where the primary threads cross. Aperture subcircular; labium smooth, standing free at the anterior end, appressed at the posterior, with slight anal notch. Outer lip crenulated by about 12 paired denticles. Siphonal canal moderately long, broad and sharply recurved at tip; former canals conspicuously divergent.

Holotype: USNM 644371.

Dimensions of holotype: height, 34 mm; diameter, 20 mm. Dimension of larger paratype: height 51.5 mm; diameter, 31 mm; (locality: TU 457).

Type locality: TU 554, Chipola River, at power-line crossing (SW ¼ Sec. 17, T1N, R9W), Calhoun County, Florida.

Figured specimen: Holotype, USNM 644371.

Horizon: Chipola Formation, lower beds only; uppermost lower Miocene.

Discussion: Murex (Chicoreus) lepidotus is not unlike *Murex folidodes* Gardner with which it occurs. Gardner (1947, p. 521) stated: "A few individuals of puzzling affinities occur with *M. folidodes,* and are possibly identical with it. They differ in having only 3 primaries instead of 5 on the early whorls, and in the earlier appearance of primaries. The protoconch of these forms is small, highly polished, and smooth and includes 2 volutions . . . The dividing line between the conch and protoconch is conspicuously defined by the change in texture and by the abrupt initiation of the sculpture, both axial and spiral." There is no doubt that the specimens Gardner was describing are of this new species and better material now available clearly demonstrates that it is distinct from *M. folidodes. M. lepidotus* is a common species, particularly at the classic Chipola locality "one mile below Bailey's ferry" (TU locality 457), where more than a dozen specimens have been collected. It is restricted to the lower portion of the Chipola Formation, with specimens known only from the type locality (TU 554) and the above mentioned TU 457, which are only about ¼ mile apart. *M. folidodes* occurs at these same two localities, but is rare, with only three specimens in the Tulane collections.* *M. folidodes* may be immediately distinguished by its three varices, instead of the four of *M. lepidotus.* There is also a different appearance to the spiral ornamentation, *M. lepidotus* having a much "coarser" aspect, although microscopically the two forms are alike, both having the unusual shagreened surface.

Friedberg (1912, pl. 10, fig. 10) has figured a specimen of *Murex austriacus* Tournouër ("*M. sedgwicki* Michelotti" Hoernes, not of Michelotti) which is exceedingly close to our new species. The principal difference between the two lies in the greater number of secondary spiral threads in the European form. *M. austriacus* was described from the Tortonian of the Vienna Basin, and Friedberg also reports the species from the Helvetian of Grund, therefore *M. austriacus* seems to be younger than the Florida species and may be a descendant of the form.

Murex lepidotus, and its subspecies, *dujardinoides,* are placed in the subgenus *Chicoreus* although they are not entirely typical of the group. In their laminate varices they are more closely related to the French Miocene species, *M. dujardini* Tournouër, which is the type of an obscure subgenus *Pirtus,* proposed in 1885 by de Gregorio, but universally ignored since that time. The subgenus *Pirtus* is by any standard to be considered a *nomen oblitum* and the writer has no desire to resurrect it, for to do so would certainly jeopardize the standing of the widely-accepted *Torvomurex. Murex denudatus* (Perry), the type species of *Torvomurex,* is strikingly similar to *M. dujardini* and to our American *M. lepidotus dujardinoides.* The similarity is so striking in fact, that it is almost impossible to accept convergence as being responsible, and we must consider the Australian group as being directly descended from these Miocene species. The most obvious course is to petition the International Commission on Zoological Nomenclature to place the name *Pirtus* on the Official Index as a *nomen obitum,* however, the problem of the *nomena oblita* is yet to be satisfactorily resolved by the Commission. Therefore it was deemed

*In the USNM collection from "one mile below Bailey's ferry" there are 125 specimens of *M. lepidotus* and only 30 specimens of *M. folidodes,* so this proportion seems to be relatively constant.

better, at this time, to simply refer these forms to the broader group *Chicoreus*. Ultimately they probably should be placed in the subgenus *Torvomurex*.

MUREX (CHICOREUS) LEPIDOTUS DUJARDINOIDES E. H. Vokes, n. subsp.

Plate 1, figs. 3a, 3b.

Shell large in size, whorls moderately convex. Nucleus of two smooth, slightly bulbous whorls; termination of nuclear whorls marked by appearance of ornamentation, both axial and spiral. Seven post nuclear whorls in the adult, suture appressed. Axial sculpture consists of ten equal nodes on the early whorls; on the fourth and successive post-nuclear whorls certain of these nodes are strengthened to form three varcies, with two intervarical nodes between each pair. Spiral sculpture consists of primary threads, three in number on the earliest whorls, increasing to approximately seven on the body whorl, with three additional primaries on the pillar. Intercalated between the primary threads are one secondary, and usually two tertiary threadlets. Entire surface of shell sculptured by minute laminar incrementals which give a shagreened appearance to the intervarical areas. The free edges of the varices are sharply fluted by a succession of laminae with open spinelets produced where the primary threads cross the varices. One larger open spine developed at the shoulder, and two series of large spinelets on the siphonal canal. Aperture subcircular; labium smooth, standing free at the anterior end, appressed at the posterior, with a slight anal notch. Outer lip crenulated with about 12 paired denticles. Siphonal canal moderately long, broad, and sharply recurved at tip; former canals conspicuously divergent.

Holotype: USNM 644372.

Dimensions of holotype: height, 32.5 mm; diameter, 18.5 mm.

Type locality: TU 547, Chipola River (SW ¼ Sec. 29, T1N, R9W), Calhoun County, Florida.

Figured specimen: Holotype, USNM 644372.

Horizon: Chipola Formation, upper beds only; uppermost lower Miocene.

Discussion: The subspecies *dujardinoides* differs from *M. lepidotus* s.s. in having only three varices rather than the four of the typical form. The varices of *dujardinoides* are more foliaceous and there are two intervarical nodes rather than the one of *M. lepidotus*. This new subspecies is fairly common occurring only in the upper portion of the Chipola Formation, with paratype material from TU localities 458 and 453. The two forms are mutually exclusive with *M. lepidotus* confined to the lower part of the formation. *M. folidodes* Gardner, which is also confined to the lower Chipola, differs from this new subspecies in the nature of the spiral ornamentation. As with *M. lepidotus,* the subspecies *dujardinoides* also has a much "coarser" aspect to the ornamentation, *M. folidodes* may be further distinguished by the presence of only one intervarical node, in contrast to the two nodes of *dujardinoides*.

Both *M. lepidotus,* and especially *dujardinoides* are exceedingly close to the French species *M. dujardini* Tournouër from the middle Miocene of the Loire Basin. A common species, *M. dujardini* is said by Glibert (1952a, p. 292) to possess three or four varices, with usually two intervarical nodes. Our Chipola species is scarcely to be distinguished from the French one. The principal difference between the two forms is the more cancellate appearance of the early whorls of *M. dujardini*. In the French species the spiral ornamentation is equal in strength to that of the axial nodes, while in the American form the axial nodes are relatively much stronger, giving a "nodose" rather than "cancellate" aspect to the first three post-nuclear whorls. In addition there is a reduction of the number of intervarical nodes from two to one in the larger specimens of *M. dujardini,* but this reduction is not found in the American form.

In the collections of the Academy of Natural Sciences of Philadelphia there is a worn specimen (ANSP 4003) collected by William Gabb, said to be from the Miocene of Santo Domingo. As best as can be determined this specimen is the same as our *dujardinoides* and extends the geographic range of the species considerably. The exact horizon is not known so that the effect upon the stratigraphic range cannot be ascertained. It is a large specimen 46.5 mm in height (incomplete), however this is not unusual for one battered specimen in the Tulane collections measures over 50 mm (TU locality 453).

Subgenus PHYLLONOTUS Swainson, 1833

Type species: *Murex imperialis* Swainson (not *M. imperialis* Fischer, = *M. pomum* Gmelin), by subsequent designation, Swainson, 1833.

MUREX (PHYLLONOTUS) DORMANI
E. H. Vokes, n. sp.
Plate 2, figs. 3a, 3b.

Shell of moderate size. Nucleus smooth, 3½ whorls ending at a small varix or riblet. Post-nuclear whorls convex, about five in the adult; suture deeply impressed. Axial sculpture consists of three high, rounded varices, which bear a single open spine at the shoulder, commonly lost in the adult. Varices excavated behind, irregularly placed with respect to the corresponding varix on the previous whorl. Between each pair of varices is one strong intervarical node (sometimes two in the younger stages). Spiral ornamentation exceedingly variable, with a tendency toward one primary thread on the shoulder, and three to six secondaries and tertiary threadlets between the suture and this first primary. Usually two or three secondary threadlets between the first and the second primary thread which is at the periphery; few secondaries and no tertiaries on the remainder of the whorl, in general only primaries, about 15 on the body whorl, becoming obscure on the pillar. Aperture oval, labium smooth, distinct, separate from body wall at anterior end. Outer lip with about eight denticles internally. Anterior canal moderately long, recurved; antecedent canals forming an anterior fasciole.

Holotype: USNM 644373.

Dimensions of holotype: height (incomplete), 22 mm; greatest diameter, 14.8 mm.

Type locality: Byram, Mississippi.

Figured specimen: Holotype, USNM 644373.

Horizon: Byram Marl, middle Oligocene.

Discussion: This Oligocene form is much like *M. mississippiensis* Conrad from the Vicksburg Group. It differs from that species in the more irregular spiral ornamentation and an overall smoother appearance. Also it usually has one strong intervarical node, in contrast to the two weaker ones of *M. mississippiensis. M. dormani* is placed in the subgenus *Phyllonotus* more because of its resemblance to *M. mississippiensis* and later species which are obviously descended from this line and which do belong in *Phyllonotus* than because of any strong morphological alliance with the group.

M. dormani is named in honor of Mr. James H. Dorman, who collected the type material.

MUREX (PHYLLONOTUS) INFREQUENS
E. H. Vokes, n. sp.
Plate 1, figs. 4a, 4b.

Shell of moderate size, spire elevated. Nucleus consists of four polished, conical whorls, terminating in a crescentric varix. Seven post-nuclear whorls in the adult, more or less convex. Early post-nuclear whorls ornamented by 14 equal axial nodes, which are crossed by three spiral threads. On the third to fourth whorls three of these axial nodes become stronger, forming varices, with the others remaining as intervarical nodes; two to three between each pair of varices. Spiral sculpture consists of four to five primary threads on the medial portion of the shell with one secondary and two tertiary threadlets between each pair of primary threads; approximately 12 primary threads on the body whorl and pillar. On the anterior portion of the varices and on the extended siphonal canal small open spinelets are produced where the primary threads cross. Aperture oval in shape, labium thin, slightly flaring, marked by numerous rugae which are a reflection of the underlying ornamentation; weak posterior anal notch. Outer lip crenulated by 12 to 14 paired denticles. Siphonal canal short, broad, recurved.

Holotype: USNM 644374.

Dimensions of holotype: height, 36 mm; diameter, 19 mm.

Type locality: TU 458, Chipola River above Farley Creek (Center Sec. 20, T1N, R9W), Calhoun County, Florida.

Figured specimen: Holotype, USNM 644374.

Horizon: Chipola Formation, uppermost lower Miocene.

Discussion: This new species may represent the form cited by Gardner (1947, p. 522, pl. 53, fig. 7) as "incertae sedis," based on an immature specimen. *M. infrequens,* as the name implies, is a rare shell, and may be confused with the more common *M. lepidotus dujardinoides,* with which it oc-

curs. It differs from that form in its almost complete lack of varical fronds. It may also be distinguished by the irregularity of the varices, in contrast to the regular procession of the varices along the spire-whorls of *dujardinoides. M. infrequens* is found throughout the Chipola Formation, paratype material occurring at TU localities 547, 196, and 70.*

Murex infrequens is the earliest species to exhibit the flaring inductura on the parietal wall which is so conspicuous in the Recent forms of *Phyllonotus.* The older species such as *M. mississippiensis* Conrad and *M. trophoniformis* Heilprin which seem to be ancestral to the line do not have this characteristic feature. The one trait that all of the members of *Phyllonotus* share is the irregular placement of the varices on the successive whorls. In all other groups of the Muricinae the varices follow in a regular series forming either a straight or spiral line up the whorls of the spire.

MUREX (PHYLLONOTUS) RIPARIUS
E. H. Vokes, n. sp.
Plate 1, figs. 5a, 5b.

Shell moderate in size, spire elevated. Three nuclear whorls, of which the first two are smooth and noticeably flattened, the last faintly ornamented and convexly rounded; nucleus ending at strong rib-like varix. Six post-nuclear whorls in the adult, convex, with impressed suture. Ornamentation of the early whorls consists of 11 equal axial nodes crossed by four to five spiral threads. On the fourth to fifth post-nuclear whorls three of the axial nodes increase gradually in size, becoming varices on the fifth whorl, with the others forming weak intervarical nodes, one or two between each pair of varices. Spiral ornamentation consists of five primary threads with one intercalated secondary on the medial portion of the shell, and with two additional tertiary threadlets on the adult whorls only; 13 primary threads on the body whorl and pillar. Where the primary spiral threads cross the varices, small open spinelets are produced on the apertural side of the varix; these spinelets are better developed on the anterior portion of the varix, and especially on the extended siphonal canal where two fairly long spines occur. Aperture subcircular, labium smooth, somewhat appressed, with posterior anal notch. Outer lip crenulated with eight to ten denticles. Siphonal canal short, broad, recurved at anterior end.

Holotype: USNM 644375.

Dimensions of holotype: height, 22.5 mm; diameter, 12 mm.

Type locality: TU 60, Jackson Bluff, Ochlockonee River, Leon County, Florida.

Figured specimen: Holotype, USNM 644375.

Horizon: Choctawhatchee Formation, upper Miocene.

Discussion: Murex (Phyllonotus) riparius is rare, presently known only from the type locality. It occurs with a superficially similar species, which is close to the Recent *M. florifer,* but is easily distinguished by the almost complete lack of varical fronds in *M. riparius.* Even the young specimens of the *M. florifer* type show distinct foliaceous varices which are never developed in this new species. *M. riparius* appears not unlike the Recent *M. consulae* Verrill (*M. pulcher* Adams *non* Sowerby). However it lacks the greatly extended siphonal canal of that form, and the varices of *M. riparius* are not continuous up the spire as they are in *M. consuelae,* so that the resemblance is probably coincidental rather than suggestive of close relationship. The only known form with which this new species is readily comparable is the above described *Murex (Phyllonotus) infrequens* from the lower Miocene Chipola Formation. It may be distinguished from that species by the different nucleus, *M. infrequens* having four polished, conical whorls to the protoconch. In all other respects the two species are much alike, but with this noticeable difference in the nature of the nuclei there is some question whether they are as closely related as they would appear.

Subgenus MUREXIELLA Clench and Pérez Farfante, 1945

Type species: *Murex hidalgoi* Crosse, by original designation.

MUREX (MUREXIELLA) MACGINTYI FACETUS E. H. Vokes, n. subsp.

Plate 2, figs. 4a, 4b.

Murex (*Chicoreus*?) *Burnsii* Whitfield. DALL, 1890, Wagner Free Inst. Sci., Trans., v. 3, pt. 1, p. 141. (*Nomen nudum*)

* There are 8 specimens in the USNM collection from "one mile below Bailey's ferry" (TU locality 457), although the writer has not yet found any there.

Not *Murex* (*Pteronotus*) *Burnsii* ALDRICH, 1894, Nautilus, v. 7, no. 9, p. 98, pl. 4, figs. 4, 4a. (January)
Murex shilohensis var. *burnsi* WHITFIELD, 1894, U.S.G.S. Mon. 24, pt. 3, p. 98, pl. 17, fig. 2. (Post-March, 1894, *fide* advertisement, p. vi)
Murex burnsi Whitfield. ALDRICH, 1895, Bull. Amer. Paleontology, v. 1, no. 2, p. 14. (Not *Murex burnsii* Aldrich, 1894)
Chicoreus burnsii (Whitfield). DALL, 1915, U. S. Natl. Mus. Bull. 90, p. 75.
Murex (*Chicoreus*) aff. *burnsii* Whitfield. GARDNER and ALDRICH, 1919, Acad. Nat. Sci. Phila., Proc., v. 71, p. 18.
Muricidea burnsi (Whitfield). RICHARDS and HARBISON, 1942, Acad. Nat. Sci. Phila., Proc., v. 94, p. 212, pl. 19, fig. 10.

Shell moderate in size, body whorl greatly inflated. Nucleus of 1½ smooth, rounded whorls; six post-nuclear whorls in the adult. Spiral sculpture consists of sharply raised ribs, two in number on the early whorls, five on the body whorl. Axial sculpture consists of six to seven varices; where the spiral ribs cross the varices long, recurved, foliaceous, open spines are produced. In addition, one spine is formed where no rib is present between the suture and the shoulder, and two spines are produced on the extended siphonal canal. The intervarical space is patterned with microscopic spiral lirae and growth lines which give a reticulate surface. The varices are formed of finely laminate layers, creating a complex webbing between the spines. Aperture subcircular; labium completely free, erect, and smooth; the outer lip bearing six grooves corresponding to the varical spines. Siphonal canal moderately long and recurved, the succession of previous canals forming an anterior fasciole.

Holotype: USNM 644376.

Dimensions of holotype: height, 24 mm; greatest diameter, including terminal varix, 18 mm.

Type locality: TU 520, canal ⅓ mile east of Brighton, Highlands County, Florida.

Figured specimen: Holotype, USNM 644376.

Horizon: ? Tampa Limestone, lower Miocene. Kirkwood Formation, middle Miocene. Choctawhatchee Formation, and Brighton beds, upper Miocene.

Discussion: Murex macgintyi facetus may be distinguished from *M. macgintyi* s.s. by the much shorter spire and more inflated body whorl of the subspecies. The varices are more foliaceous and the spines are much longer, so that the subspecies resembles *Murex hidalgoi,* the type of *Murexiella,* to a strong degree, although in *M. hidalgoi* the spines are not recurved as in *facetus.* This new form is no doubt ancestral both to *M. hidalgoi* and to *M. macgintyi,* as well as to

---

PLATE II

Page

1a, 1b. *Murex* (*Panamurex*) *gilletteorum,* n. sp. (X 1½) ---- 160
USNM 644377 (holotype); height 43.5 mm, diameter 26 mm.
Locality: TU 562. Silverdale beds.

2a, 2b. *Murex* (*Panamurex*) *clarksvillensis* (Mansfield) (X 2) ---- 161
USNM 644378; height 31.4 mm, diameter 15 mm.
Locality: TU 60. Choctawhatchee Formation.

3a, 3b. *Murex* (*Phyllonotus*) *dormani,* n. sp. (X 2) ---- 156
USNM 644373 (holotype); height 22 mm, diameter 14.8 mm.
Locality: Byram, Mississippi, Byram Marl.

4a, 4b. *Murex* (*Murexiella*) *macgintyi facetus,* n. subsp. (X 2) ---- 157
USNM 644376 (holotype); height 24 mm, diameter 18 mm.
Locality: TU 520. Brighton beds.

5a, 5b. *Tritonalia* (*Tritonalia*) *festivoidea,* n. sp. (X 2) ---- 161
USNM 644379 (holotype); height 24 mm, diameter 14 mm.
Locality: TU 562. Silverdale beds.

6 - 7. *Tritonalia* (*Miocenebra*) *silverdalense,* n. sp. (X 2) ---- 162
6a, 6b. USNM 644380 (holotype); height 28.5 mm, diameter 12.4 mm.
7a, 7b. USNM 644381 (paratype); height 18 mm, diameter 9 mm.
Locality: TU 562. Silverdale beds.

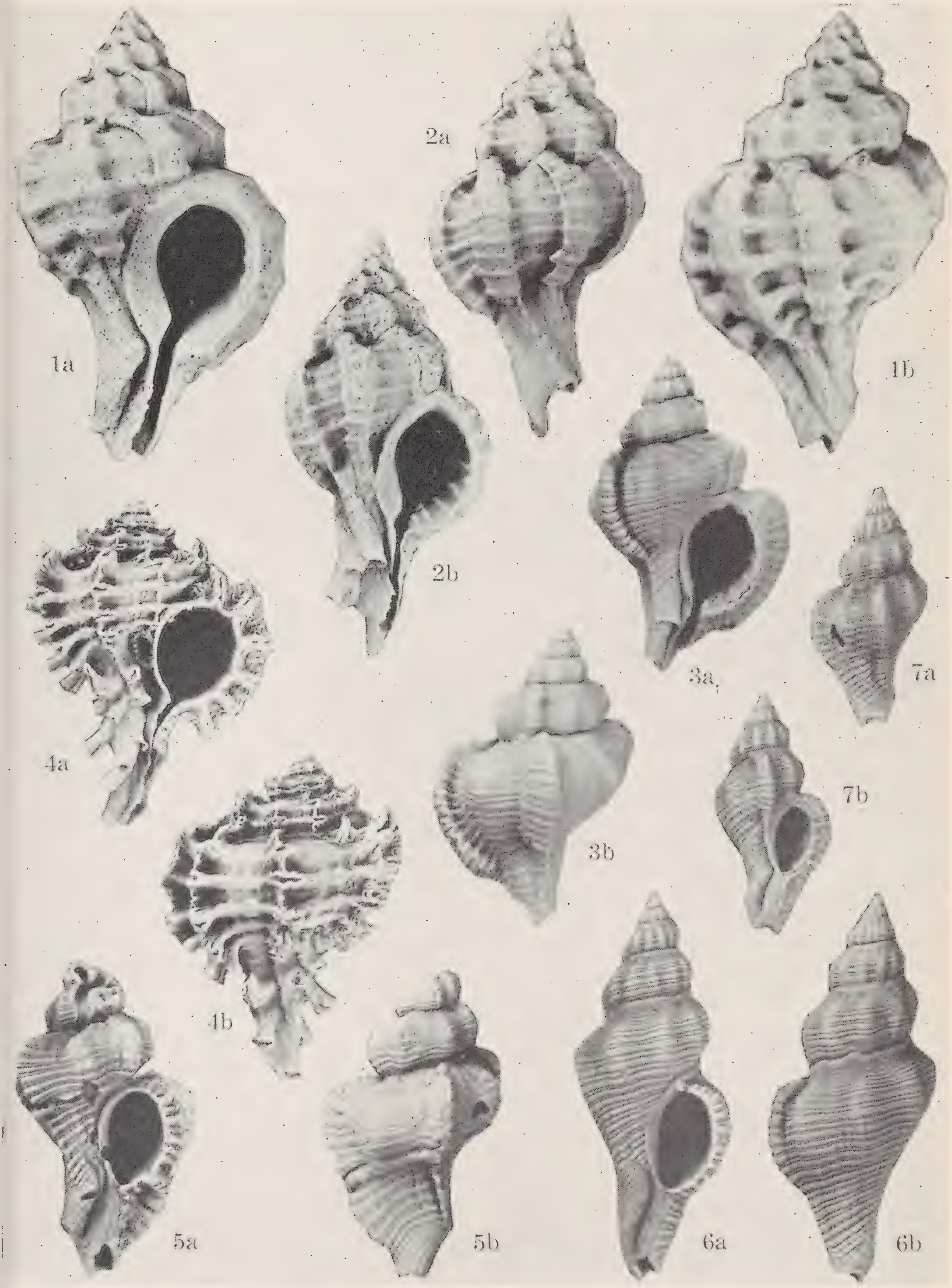

PLATE II

M. humilis Broderip from the west coast of Panama.

The history of this taxon is exceedingly complicated. It was first mentioned by Dall (1890, p. 141) who said: "The truncated specimen, upon which Prof. Whitfield has founded his variety *Burnsii,* belongs, in my opinion, to a different species and subgenus [than *Murex shilohensis*]." Dall was referring to a name which was still in manuscript, for although Whitfield's report had been transmitted to the Director of the U. S. Geological Survey in 1889, it was not published until after March, 1894. Unfortunately, before Whitfield's monograph reached the public, another *Murex burnsi* (named for the same man, Frank Burns of the U.S. National Museum) had been described by Aldrich from the lower Oligocene at Red Bluff, Mississippi. Matters would be greatly simplified if it were possible to consider Whitfield's *burnsi* as being validated by Dall in 1890, but there is no true description given by Dall, and the name is a *nomen nudum* at this point. Dall did compare the species with *Murex interserratus* Sowerby, stating that "the young shell . . . is the complete image of *Murex interserratus* Sby. of the same age. The last species is still living in the southeastern Antilles in deep water. It is, of course, impossible to say how much *M. Burnsii* would, in the adult state, differ from the living shell." The "*Murex interserratus*" of Dall has been identified by Clench and Pérez Farfante (1945, p. 48) as *Murex carnicolor,* not *M. interserratus,* and this species is not even to be referred to the same subgenus as *M. burnsi,* so that Dall's comparison is scarcely valid. Aldrich, however, considered that his name was preoccupied by Dall's usage, and so in 1895, unnecessarily changed his *burnsi* to *M. grandispinosa.*

Because Whitfield's type specimen is incomplete, absolute identification with our new form is not possible. Therefore it was deemed advisable, as a new name was necessary for the preoccupied *burnsi,* to select a new type specimen for the form here described. Although the two forms are in all probability synonymous, the writer does not wish to consider this taxon as a new name for *M. burnsi* Whitfield, but rather as a new subspecies of which *burnsi* is considered a synonym.

M. macgintyi facetus is not uncommon in the upper Miocene of Florida. It occurs at Jackson Bluff, Leon County (TU locality 60), in northern Florida, and at the type locality in southern Florida. Whitfield described *burnsi* from the beds at Jericho, New Jersey, which have now been assigned to the Kirkwood Formation, of middle Miocene age (Richards and Harbison, 1942). If Dall's report of the occurrence of this species from the Tampa "Silex Beds" at Ballast Point is correct then the species ranges from the lower through the upper Miocene. The Pliocene form is *M. macgintyi* s.s.

McGinty described a species, *"Tritonalia" graceae* from Belle Glade, Florida which is similar to *Murex macgintyi.* From the description it might be confused with our new form, however, his illustration shows a very different shell, much attenuated, with a long, slim canal and a coronet of long shoulder spines.

Subgenus PANAMUREX Woodring, 1959.

Type species: *Murex gatunensis* Brown and Pilsbry, by original designation.

MUREX (PANAMUREX) GILLETTEORUM E. H. Vokes, n. sp.

Plate 2, figs. 1a, 1b.

Shell large for the group, and heavy. Nucleus unknown, seven post-nuclear whorls in the adult. Axial ornamentation consists of six to seven stout rib-like varices; the spiral ornamentation of four strong, raised ridges, which ride up over the varices. Between these conspicuous spiral ridges the shell is patterned with irregular microscopic spiral lirae and axial growth lines giving a semi-reticulate appearance. Aperture ovate, labium heavy, standing free in the anterior portion, somewhat appressed posteriorly. Outer lip denticulate, with about ten more or less well defined teeth. Canal moderate in length, slightly recurved, and open.

Holotype: USNM 644377.

Dimensions of holotype: height, 43.5 mm; greatest diameter, 26 mm.

Type locality: TU 562, Onslow County marl-pit, near Silverdale, Onslow County, North Carolina

Figured specimen: Holotype, USNM 644377.

Horizon: Silverdale beds, lower Miocene.

Discussion: This species is most closely related to *Murex* (*Panamurex*) *laccapoius*

(Gardner) from the Chipola Formation (uppermost lower Miocene) and *Murex* (*Panamurex*) *clarksvillensis* (Mansfield) from the Choctawhatchee Formation (upper Miocene) of northwestern Florida. It differs from these two species primarily in its larger size, but it also has proportionally much heavier spiral ornamentation. The type material is worn and does not exhibit the characteristic *Panamurex* rugae on the anterior portion of the labium, but these may appear on better specimens.

The exposures of marl at Silverdale, North Carolina, were assigned to the "Trent Marl" by Kellum (1926, p. 13), and that author concluded that the age of the formation was lower Miocene. However the Trent was originally described as being overlain by the upper Eocene Castle Hayne Formation and therefore some question exists concerning the assignment of the Silverdale beds to the Trent. There seems to be little doubt that the Silverdale fauna is of lower Miocene age, and the writer prefers not to use the term "Trent Marl" in conjunction with the Silverdale material until the question is settled.

Murex (*Panamurex*) *gilletteorum* is presently known only from the type locality where it is relatively rare, with just four specimens being found after intensive collecting. This species is named for Mr. and Mrs. John Gillette, of Silverdale, North Carolina, for their years of kindness to marauding paleontologists.

MUREX (PANAMUREX) CLARKSVILLENSIS (Mansfield)

Plate 2, figs. 2a, 2b.

Muricidea clarksvillensis MANSFIELD, 1937, Jour. Paleontology, v. 11, no. 7, p. 610, pl. 85, fig. 6.

"Shell of moderate size; solid; spire about one-third length of shell; axial sculpture stronger than spiral; consisting of 5 whorls, nucleus decollated. Whorls rounded, weakly tabulated in front of the rather deep suture and rapidly and uniformly expanding. Spiral sculpture consisting of rather strong primary threads (13 on body whorl and canal) over-running axials and interspaces and usually of a secondary intermediate threadlet. Ribs 6, extending from suture to suture on the spire whorls and to the end of the canal on the body whorl. Aperture axially ovate. Outer lip within provided with 8 widely spaced spiral lirations. Inner lip with a thin callus and bearing on its anterior third 3 lirations. Canal rather short and recurved; the raised margin of the canal and the siphonal fasciole separated by a small chink.

"Dimensions of holotype (U. S. Nat. Mus. 496424): Length, 30 mm; diameter, 17 mm." (Mansfield, 1937)

Figured specimen: USNM 644378; height, 31.4 mm; diameter, 15.0 mm. Locality: TU 60, Jackson Bluff, Ochlockonee River, Leon County, Florida.

Horizon: Choctawhatchee Formation, upper Miocene.

Discussion: The worn holotype of *"Muricidea" clarksvillensis,* the only specimen heretofore figured, does not exhibit the distinctive characteristics possessed by better specimens. Therefore a more perfect example is here shown in order to demonstrate the subgeneric affinities of Mansfield's species. From this specimen it can be seen that *M. clarksvillensis* resembles *Murex gatunensis,* the type of *Panamurex,* and should be assigned to that subgenus. It should be noted that the recognition of this subgenus in the upper Miocene Choctawhatchee Formation extends the geological range for the *Panamurex* group, previously cited by Woodring (1959, p. 217) as "late middle Miocene." Moreover, in addition to *M. clarksvillensis,* another Choctawhatchee species, *"Muricidea?" alaquaensis* Mansfield, described from Walton County, Florida, also is to be referred to *Panamurex.*

Subfamily TRITONALIINAE

Genus TRITONALIA Fleming, 1828

Subgenus TRITONALIA s.s.

Type species: *Murex erinaceus* Linné, by subsequent designation, Gray, 1847.

TRITONALIA (TRITONALIA) FESTIVOIDEA, E. H. Vokes, n. sp.

Plate 2, figs. 5a, 5b.

Shell moderate in size, spire elevated, suture deeply constricted giving a much inflated aspect to the individual whorls. Nucleus unknown, about five post-nuclear whorls in the adult. Axial ornamentation consists of three wing-like varices, which are sculptured with minute imbrications on the apertural side. Between each pair of varices is one very strong node. Spiral ornamentation consists of coarse threads alternating with usually three finer threadlets between each pair; about 18 primary threads on the body whorl and pillar. At the juncture of the body whorl and the pillar there is a

raised rib which corresponds to an ill-defined anterior apertural tooth and is a conspicuous spiral ridge. Aperture oval, labium distinct, not appressed. Outer margin of the aperture denticulate, with about four weak teeth. Canal moderate, slightly recurved, completely roofed over to form a tubular structure typical of *Tritonalia.*

Holotype: USNM 644379.

Dimensions of holotype: height (incomplete), 24 mm; greatest diameter, 14 mm.

Type locality: TU 562, Onslow County marl-pit, near Silverdale, Onslow County, N. C.

Figured specimen: Holotype, USNM 644379.

Horizon: Silverdale beds, lower Miocene.

Discussion: Tritonalia festivoidea, as the name would suggest, resembles *Tritonalia festiva* (Hinds) from the Recent of the California Coast. The Silverdale species differs from the Recent one in its smaller size, and in the nature of the spiral sculpture, the threads of *festiva* being of a uniform width. The varices of the fossil are much less expanded and recurved than the Recent form, but they share the imbricate structure. The preservation of the type material is not good, and the description is a composite of the three specimens which were collected.

Glibert (1952a, pl. 7, figs. 6a, 6b) has figured a specimen from the middle Miocene of France which is very similar to our Carolina form. This specimen is assigned by Glibert to *Tritonalia dufrenoyi* (Grateloup) but the typical *dufrenoyi* does not bear this strong resemblance, and it is possible that Glibert's shell may represent a different species. Nevertheless the relationship of *festivoidea* and the European species should be noted. Friedberg (1912, pl. 10, fig. 3) figured a shell which he called "*Ocenebra erinacea* Linné" from the Miocene of Poland that is also close to this new species. The original reference is in an obscure publication but the specimen has been refigured by both Korobkov (1955, pl. 71, figs. 7a, 7b) and Orlov, *et al.* (1960, figs, 527a, 527b). Orlov cites the species as being from the Tortonian or upper Miocene of the Ukraine.

MIOCENEBRA E. H. Vokes, n. subgen.

Type species: *Tritonalia (Miocenebra) silverdalense* E. H. Vokes, n. sp.

Diagnosis: Shell greatly elongated, spire much elevated, constricted above the shoulder with an appressed suture. Formation of the varices irregular, with one always present at the aperture, although the others may be reduced to strong nodes. Aperture oval, margin complete, outer lip slightly crenulated. Canal elongated and completely closed over to form a tubular structure.

This new subgenus differs from the typical *Tritonalia* (type: *Murex erinaceus* Linné) in having the shell greatly elongated. In the elongate form this subgenus perhaps resembles *Pteropurpura* (type *Murex macropterus* Deshayes) most nearly, but differs in lacking the greatly expanded wing-like varices of that group. *Miocenebra* is similar to *Tritonalia* in the tubular canal, a trait which is found in many groups of the Tritonaliinae, in the irregular formation of the varices, details of the early whorls, and the structure of the aperture.

TRITONALIA (MIOCENEBRA) SILVERDALENSE E. H. Vokes, n. sp.

Plate 2, figs. 6a, 6b, 7a, 7b.

Shell moderate in size, spire greatly elevated, whorls constricted above the shoulder, with an appressed suture that is sinuated by the axial nodes. Six adult whorls, nucleus unknown. Axial sculpture on the early whorls consists of about 12 equal nodes, which gradually diminish to about seven unequal nodes on the body whorl. Of these seven nodes, three are stronger, giving the appearance of varices, but there is no evidence of a break in the shell deposition, so that these are not true varices except at the aperture. Spiral sculpture consists of irregularly alternating weak and strong cords. Each strong cord has a medial groove which separates it into what appears to be two, however if the specimen is worn this groove disappears and the cord seems to be a single wide one. There are perhaps as many as 30 primary spirals on the body whorl and pillar of an adult specimen. Aperture oval, slightly crenulated within the labrum by grooves which correspond to the major external cords. Siphonal canal long, completely closed over by an extension from the columella, to form a tubular structure.

Holotype. USNM 644380; paratype: USNM 644381.

Dimensions of holotype: height, 28.5 mm; greatest diameter, 12.4 mm.

Dimensions of immature paratype: height, 18 mm; diameter, 9 mm.

Type locality: TU 562, Onslow County marl-pit, near Silverdale, Onslow County, N. C.

Figured specimens: Fig. 6, Holotype, USNM 644380; Fig. 7, Paratype, USNM 644381.

Horizon: Silverdale beds, lower Miocene.

Discussion: There is no species known from the Tertiary of the Atlantic and Gulf Coastal Plains with which this new form can be compared. Glibert (1952b, pl. 7, figs. 14a, 14b) has figured a specimen from the middle Miocene of Bolderberg, Belgium, said to be *Murex poelmanni* Geraerts, which seems to be referable to *Miocenebra,* but no other form has been found which appears closely related to this new subgenus.

IV. Locality Data

The following are Tulane University locality numbers:

60. Choctawhatchee Fm., Borrow pit at Jackson Bluff, Ochlockonee River (NW¼ Sec. 21, T1S, R4W), Leon Co., Florida.

70. Chipola Fm., Ten Mile Creek, at bridge of Florida Highway 73 (NW¼ Sec. 12, T1N, R10W), Calhoun Co., Florida.

196. Chipola Fm., Ten Mile Creek, about ½ mile upstream from bridge of Florida Highway 73 (NE¼ Sec. 11, T1N, R10W), Calhoun Co., Florida.

453. Chipola Fm., lowest beds at Alum Bluff, Apalachicola River (SE¼ Sec. 24, T1N, R8W), Liberty Co., Florida.

457. Chipola Fm., west bank of Chipola River, (SW¼ Sec. 17, T1N, R9W), Calhoun Co., Florida.

458. Chipola Fm., east bank of Chipola River, above Farley Creek (Center Sec. 20, T1N, R9W), Calhoun Co., Florida.

520. Unnamed formation, spoil banks, canal ⅓ mile east of Brighton, Highlands Co., Florida.

547. Chipola Fm., west bank of Chipola River (SW¼ Sec. 29, T1N, R9W), Calhoun Co., Florida.

554. Chipola Fm., east bank of Chipola River, just below power line crossing (SW¼ Sec. 17, T1N, R9W), Calhoun Co., Florida.

562. Silverdale beds, marl-pit on south side of Webb Creek about ¾ mile southwest of Silverdale, Onslow Co., North Carolina. [This pit is approximately across Webb Creek from the old "Gillette" marl-pit.]

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CONTENTS

VOLUME 2

NUMBER — PAGE

1. THE EVOLUTION OF THE EUCARIDA, (CRUSTACEA, EUMALACOSTRACA), IN RELATION TO THE FOSSIL RECORD
   Martin D. Burkenroad 3

   ADDITIONS TO A CATALOGUE OF THE DESCRIBED RECENT AND TERTIARY SPECIES OF *ACESTA* AND *PLICACESTA*
   Harold E. Vokes 18

2. THE RACCOON (*PROCYON*) IN THE PLEISTOCENE OF NORTH AMERICA
   Andrew A. Arata and J. Howard Hutchison 21

   A MISTAKEN REPORT OF A PECCARY FROM THE PLEISTOCENE OF LOUISIANA
   Andrew A. Arata 28

   GEOLOGY OF THE LAVON AREA, COLLIN COUNTY, TEXAS
   R. O. Steinhoff 29

   THE GENUS *TURBINELLA* (MOLLUSCA, GASTROPODA) IN THE NEW WORLD
   Emily H. Vokes 39

3. THE SPECIES AND STRATIGRAPHIC DISTRIBUTION OF *CAUCASINA* AND *AEOLOMORPHELLA,* NEW GENUS (FORAMINIFERIDA)
   Alfred R. Loeblich, Jr. and Helen Tappan 69

   COSTELLACESTA, A NEW SUBGENUS OF *LIMA* FROM THE CRETACEOUS OF THE GULF AND ATLANTIC COAST PROVINCE
   Erle G. Kauffman 89

   THE STATUS OF *DEIROCHELYS FLORIDANA* HAY WITH COMMENTS ON THE FOSSIL HISTORY OF THE GENUS
   C. G. Jackson, Jr. 103

   PRINCIPLES OF PALEOECOLOGY: A REVIEW
   Hubert C. Skinner 107

4. MIOCENE PLANKTONIC FORAMINIFERA FROM NEWPORT BAY, CALIFORNIA
   Jere H. Lipps 109

   MARGARITARIIDAE, NEW FAMILY (PELECYPODA) AND DESCRIPTION OF TWO NEW SPECIES
   Harold E. Vokes 135

   REVIEWS: TIME IN STRATIGRAPHY; NATURAL HISTORY; INTRODUCTION TO GEOLOGICAL MICROBIOLOGY
   Hubert C. Skinner 143

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TULANE STUDIES IN GEOLOGY

Volume 2, Number 1 December 30, 1963

THE EVOLUTION OF THE EUCARIDA, (CRUSTACEA, EUMALACOSTRACA), IN RELATION TO THE FOSSIL RECORD

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ADDITIONS TO A CATALOGUE OF THE DESCRIBED RECENT AND TERTIARY SPECIES OF *ACESTA* AND *PLICACESTA*

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Volume 2, Number 1 December 30, 1963

CONTENTS

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Page

Abstract 3
I. Introduction 3
II. The Fossil Record 4
A. Paleozoic
1. Devonian and Carboniferous 4
2. Permian 8
B. Mesozoic
1. Triassic 9
2. Jurassic 11
III. Probable Characteristics of Fossils of the Hypothetical Paleozoic Stems of Major Eucarid Taxa 14
Acknowledgments 16
Literature Cited 16

ILLUSTRATIONS

Text Figure 1. Dendrogram of Eucarid evolution 2

ADDITIONS TO A CATALOGUE OF THE DESCRIBED RECENT AND TERTIARY SPECIES OF *ACESTA* AND *PLICACESTA*

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TULANE UNIVERSITY

I. Introduction 18
II. Additions to the Catalogue of *ACESTA* 18
Recent species 18
Tertiary species 18
Species incorrectly referred to *Acesta* 19
III. Additions to the Catalogue of *PLICACESTA* 20
Literature Cited 20

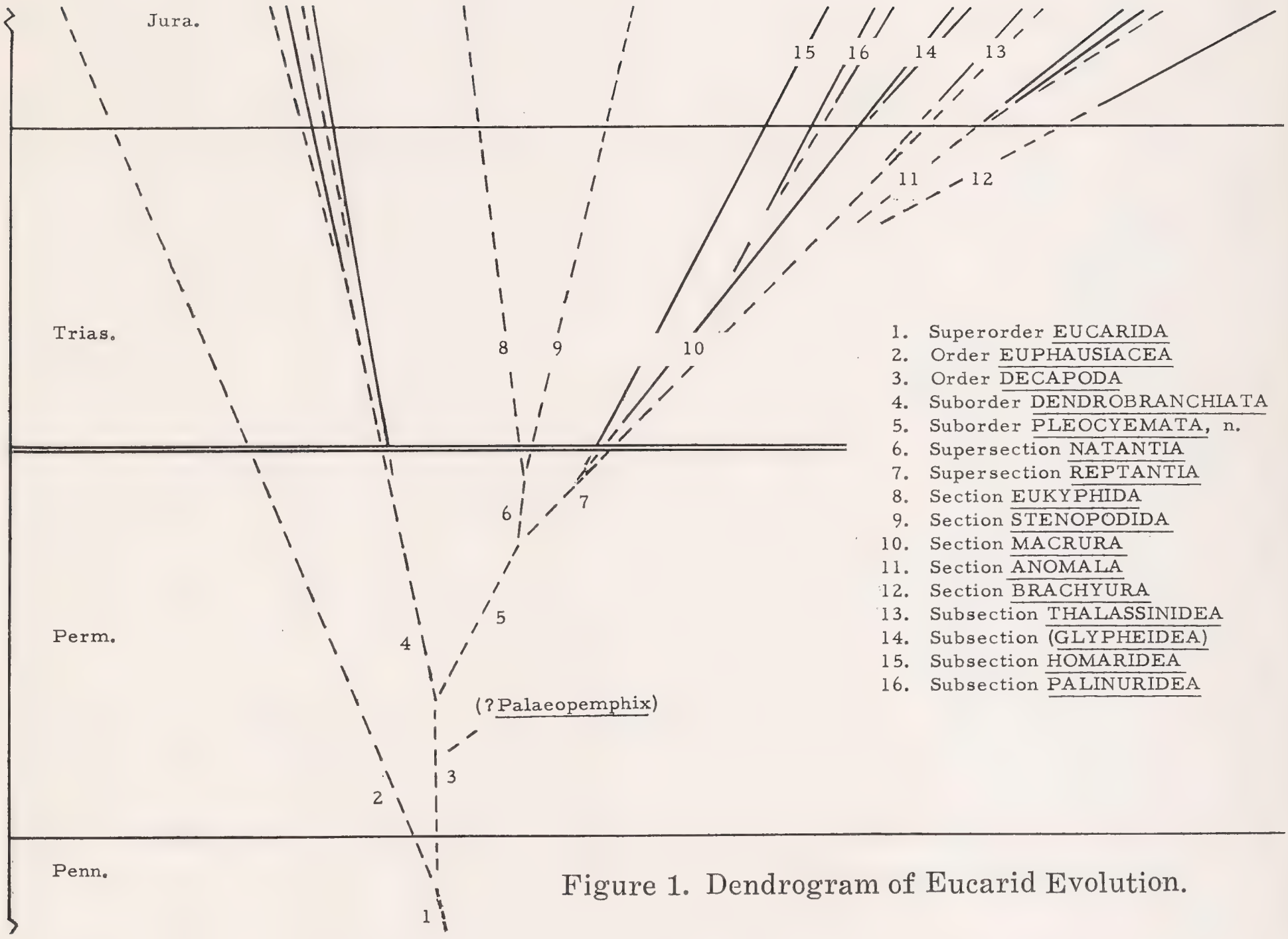

Figure 1. Dendrogram of Eucarid Evolution.

THE EVOLUTION OF THE EUCARIDA, (CRUSTACEA, EUMALACOSTRACA), IN RELATION TO THE FOSSIL RECORD

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MUSEO NACIONAL DE PANAMA

Abstract

Eumalacostracan fossils from the Mississippian indicate the beginnings of Recent superorders other than the Eucarida; which latter probably also differentiated around this time, from a primitive shrimp with carapace sculpture like that of *Palaeopalaemon,* in a marine form not yet discovered There is no valid evidence to suggest Eucarid polyphyly. The only Paleozoic record of the superorder seems to be the peculiar form *Palaeopemphix* from the Permian, which is certainly not a Glypheid but may represent an early, calcified offshoot of the stem-form of the order Decapoda (the family PALEOPEMPHICIDAE, n.). In the early Triassic, not only are the known Eucarids definitive Decapods, but this order was already differentiated into the suborders Dendrobranchiata and PLEOCYEMATA (n.), which were themselves already subdivided (*e.g.,* the Peneidae were presumably already separated from the AEGERIDAE, n. fam.). The available Mesozoic representation undoubtedly includes a disproportionate frequency of forms specialized by calcification; and this record seems too late, fragmentary and non-consecutive to supply crucial evidence either for or against the present view of Decapod phylogeny founded on evidence from Recent forms. The habits and characteristics to be expected of Paleozoic fossils representing the hypothetical stems of Eucarid groups are outlined.

I. Introduction

A new consideration of the adult and the developmental characteristics of Recent Eucarid Crustacea indicates that all previously-proposed systems of classification of the members of the order Decapoda are in various degrees polyphyletic (in the sense of grouping taxa together some of which are more closely related to members of other groups given equal rank; *cf.* Simpson, 1961, p. 120 ff.). This conclusion (for which the evidence is given in detail in a forthcoming treatment of the Recent Eucarida) necessitates a critical examination of paleontological findings, since the primary test of any phylogenetic hypothesis is its compatibility with the fossil record. The present paper is, then, a review of current paleontological ideas from the new point of view, and is offered in advance of detailed evidence from the Recent in order to secure comment on its weaknesses from specialists in fossils.

The Recent evidence indicates that the following more or less widely-accepted major taxa are monophyletic: (1) the superorder Eucarida Calman (carapace fused with all thoracic tergites, probably in relation to the habit of jumping backward; appendix masculina on male second pleopod); (2) the Eucarid order Euphausiacea Boas (body-gills entirely lost but podobranchs including that of the eighth thoracic appendage retained; specializations for sperm-transfer and for

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pelagic life; (3) the Eucarid order Decapoda Latreille (loss of the eighth epipodite and podobranch, enclosure of all gills in the branchial chamber and enlargement of the maxillary pump with correlated reduction of the muscular basal part of the pereiopodal expodites; attenuation of the endopod of the first thoracic appendage and permanent flexure of that of the second one); (4) the Decapod supersection Reptantia Boas (loss of all pleurobranchs anterior to the fifth thoracic somite; specializations for benthonic life).

The Recent evidence unequivocally indicates that the "suborder Natantia" of Boas is polyphyletic. The Peneids represent one of two major branches of the order Decapoda and require separation as the suborder Dendrobranchiata (Bate, redefined). They retained dendrobranchiae and a non-incubatory habit with naupliar eclosion from the generalized Eumalacostracan that also gave rise to the marsupial superorder Peracarida; but differentiated from the ancestral Decapod by a few unique specializations, as well as by developing chelae on the fourth to sixth thoracic legs. The other major branch of the Decapoda, for which the new suborder PLEOCYEMATA is required, lost the secondary rami of the gills and developed pleopodal incubation with zoeal eclosion, but apparently continued at first to be achelate. This incubatory branch appears to have divided early into two stems. The first-differentiated of these two, which was especially characterized by delay in appearance of the arthrobranch gills during ontogeny (supersection Natantia Boas, as here restricted) soon divided further into two highly divergent lines nowadays represented by the sections Stenopodida Huxley and Eukyphida Boas. The other offshoot of the Pleocyemate ancestor is the benthonic supersection Reptantia Boas, of which the Recent Thalassinidea (some still achelate and most still little-calcified and with a longitudinal suture on the carapace) seem on the whole to have differentiated least decisively from the Reptant ancestor (although conservative features are scattered among all Reptant groups, along with specialized ones).

The present somewhat superficial examination of the Paleozoic and Mesozoic record does not reveal any decisive evidence in favor of the above phylogenetic hypotheses, but does seem to show that the conflicting previous deductions from the known fossils are not required by the evidence. A final section of the paper outlines the probable characteristics of Paleozoic Eucarid fossils which (according to the present view) are to be hoped-for in the gap between the early, generalized Eumalacostraca known from the Devonian and the specialized Decapod genera (Peneine, Glypheid and Homaridean) so far recorded from the Permo-Trias and the early Triassic.

II. The Fossil Record

A. *Paleozoic:*

1. *Devonian and Carboniferous:* The Paleozoic Eumalacostraca have recently been extensively revised by Brooks (1962). According to him, the fossil record begins in the Devonian with three shrimplike genera believed all to have had a more or less enlarged antennular peduncle, undifferentiated biramous thoracic limbs with an undivided sympod, furcal plates on the telson (however, *cf. l.c.,* Plate 52, fig. 2; and also Howell, 1957, fig. 1) and a well-developed carapace, shorter than the pleon but covering although not fused to all thoracic tergites. Oöstegites have not been seen, although this might be "due to a deficiency of the fossils" (*l.c.,* p. 224).

One of these Devonian genera (*Palaeopalaemon*) extended into the Lower Mississippian; and during the later Mississippian and the Pennsylvanian there have been found five other shrimplike genera assigned to the same order (Eocaridacea Brooks). In Brooks's material of these later genera also, "oöstegites have not been seen . . ., but Peach . . . claimed they were present on *Crangopsis.* This needs reinvestigation" (p. 266. However, on p. 205 Brooks says that the *Crangopsis* "marsupium . . . may have been similarly developed on *Anthracophausia*"; and on p. 206, "It is inferred that a marsupium may have been present as one has been reported on a closely related genus").

During the Mississippian, fossils of a variety of other sorts of Eumalacostraca appear. One of these groups, the Palaeocaridacea Brooks, had no carapace and is assignable to the extant superorder Syncarida. A second had only a vestige of carapace (covering no more than the first two

thoracic somites) and, although tentatively assigned to the Peracarida (after Calman), is noted by Brooks, p. 268, to be a possible ancestor of, *e. g.,* the Pancarida. A third group, the Palaeostomatopoda Brooks, seems Hoplocarid (if, as stated by Brooks on p. 211, "Peach . . . mistook remains of the jointed endopods for a brood pouch in *Perimecturus elegans* . . . and the broad lobes shown on *P. pattoni* as a 'broodpouch' are probably the remains of pleopods"; which would remove the objection by Tiegs and Manton, 1958, p. 336, that "Few will support Glaessner in . . . placing the fossil Perimecturidae, possessing a typical peracaridan brood pouch, on the ancestry of the Hoplocarida").

A fourth group, which is first known from the Mississippian but mostly from the Pennsylvanian and the Permian (Pygocephalomorpha Beurlen as restricted by Brooks), consists of forms distinguished from Brooks's Eocaridacea by having a cephalothorax at least no shorter than the pleon and a "Branchiostegal development of the pleura of the carapace" (described for *Anthracaris,* p. 177, as an infolding of the lower edge of the broadened carapace, which fits "against the flanks of the thoracic somites just above the coxa of the legs to form a crablike branchial chamber"). Of these forms, *Anthracaris* had a sperm-receptacle on the last thoracic sternite of the female (p. 184, pl. 2 and 39) and no oöstegites (pp. 173, 265). *Tealliocaris* had oöstegites and no sperm-receptacle (p. 265 and pl. 7). *Pygocephalus* "not only has a peracarid marsupium, but the seminal receptacle diagnostic of syncarids and decapods" (p. 265. However, Woodward's figure of *Pygocephalus,* in which Brooks recognizes a sperm-receptacle, is said not to show oöstegites; and Brooks, p. 198, says that Woodward interpreted the "receptacle" as a "doubtful (anal?) plate displaced"). In the other five Pygocephalomorph genera listed by Brooks, it does not seem to be known whether the female had either oöstegites or a sperm-receptacle. In the Pygocephalomorphs from the southern hemisphere, the pleon was flexed under the cephalothorax, a crab-like convergence.

Brooks unites the Devonian and Carboniferous forms having a well-developed carapace as the superorder Eocarida Brooks, since "a vertical classification . . . would obscure the tenuousness of the inferred phylogenetic relationships" (p. 274). The members of this new superorder are "unique in that all have biramous thoracic appendages with a single joint in the sympods and furcal lobes and a median spine on the telson" (p. 265). However, since the six-jointed anterior thoracic appendages described for the Paleostomatopod *Archaeocaris* are neither biramous nor unique but would resemble those of the Recent Hoplocarida, it might be better not to include Brooks's Palaeostomatopoda in the same superorder with his Eocaridacea and Pygocephalomorpha.

The described distinctions between Eocaridacea and Pygocephalomorpha seem of doubtful significance when considered in relation to the diversity within these two groups. The Eocaridacean *Paleopalaemon,* with cephalothorax "only slightly reduced in length" and "an incipient branchiostegal development of the pleurae of the carapace" may, as Brooks thinks, represent the type from which "the Pygocephalomorpha evolved" (p. 266); but some Eocaridacea possess, whilst others seem to lack, the definitive Peracarid specialization (brood-lamellae). It seems more likely that Pygocephalomorpha with oöstegites were an offshoot of some similarly marsupial Eocaridacea such as must also have given rise to the Mysidacean Peracarida (since an oöstegite-formed marsupium is presumably correlated with abbreviated development, and such a trait seems too complex to have much probability of appearing more than once; although it can be lost, *cf.* Bovallius, 1890, p. 31). The sperm-receptacle on the last thoracic sternite of *Anthracaris* suggests that this form might have descended from some Eocaridacea which similarly lacked oöstegites but had a sperm-receptacle, other descendants of which lost the carapace (by hysterotely?) and gave rise to the Syncarida (although sperm-receptacles are not very safe indicators of relationship, having been independently developed many times on various somites of Malacostraca; *cf.* Andrews, 1905, pp. 48-9, on Homaridea and Burkenroad, 1936, pp. 62-3 on Peneids). It thus seems possible that the distinction made by Brooks between Pygocephalomorpha and Eocaridacea is between polyphyletic grades (like the original Decapod

suborders "Macrura" and "Brachyura") rather than between homogeneous taxa, and that his restricted "Pygocephalomorpha" are merely "the Paleozoic benthonic Eumalacostracans" (p. 265), convergent from diverse natant "Eocaridacea."

Brooks then suggests polyphyletic descent of the Eucarida from members of his "Eocaridacea" and "Pygocephalomorpha," as follows: (1) "Recent euphausids have retained the primitive telson and are probably specialized pelagic descendants of" the "Eocaridacea" (p. 266). (2) "The Penaeidae may have evolved from the Eocaridacea" (p. 270; and *cf.* Brooks's phylogenetic diagram, plate 16, where the line with a question mark, which evidently represents the differentiating Peneids, is drawn entirely independent of the Euphausiid and Reptant lines). (3) "Though *Anthracaris* from the Pennsylvanian has some characteristics of the eryonid decapods, it is a pygocephalomorph" (p. 269); and "It should be noted that the Decapoda may be polyphyletic. . . . The Eryonidae probably evolved from the Pygocephalomorph" (p. 270).

Brooks's suggestion of Eucarid polyphyly would imply that the definitive Eucarid specialization (carapace fused to all thoracic tergites) arose convergently on several occasions. However, this seems improbable; especially because Euphausiids and Decapods have in common a second, independent, peculiar specialization, not previously taken into consideration by taxonomists; namely, the bifurcation of the appendix interna of the second male pleopod to form an appendix masculina. A rigorous examination of Brooks's evidence thus seems to be required, as follows:

(a) The stated reason for deriving the Euphausiids from the "Eocaridacea" directly rather than as a branch of the Eucarid line (their "primitive telson") is elaborated by Brooks on p. 168, as follows: "all fossils except the syncarids have a pair of furcal lobes and a median spine on the telson. A furca is known in adult Recent Eumalacostraca only on euphausids and the syncarids of the Order Bathynellacea. The median spine is known only in the adults of euphausids. Gurney (1942, pp. 116-123) noted the occurrence of these structures of the telson in ontogenetic stages of the Eumalacostraca and concluded they are relics of a 'primitive form of telson preserved from a predecapod ancestor'. The paleontological evidence presented herein proves his deduction". However, Gurney, in the quoted suggestion ("It is possible that it is a primitive form of telson . . ."), was not referring to furcal rami, or to median spine as such, but to a peculiar pattern of telson common to some adult Mysids and Euphausiids and to some Eukyphid Decapod larvae. What he says about Euphausiacea (p. 119) is that they "afford no evidence as to the origin of the telson". The median spine, contrary to Brooks's generalization, is widely distributed; being found in some adult Mysids and Decapods (as is also an enlarged pair of spines like those of the Euphausiids, or a terminal fork suggestive of those in some of the larvae). What Gurney (1942, pp. 116-7) identified with the furcal rami of Branchiopoda, Copepoda, Leptostraca and embryonic Mysids were the forks of the larval telson of Peneid and Brachyuran Decapods, not the spines or setae borne on these forks (which he says, p. 119, "may be retained" while the forks are "absorbed into the telson and lose their individuality altogether"; *cf.* also Calman, 1909, p. 244, and Tiegs and Manton 1958, p. 295). The large "Eocarid" furcal plates shown by Brooks (setose in the restorations of the Pygocephalomorphs *Anthracaris, Mamayocaris* and *Tealliocaris;* pl. 2, 5, 7) suggest the Leptostraca, whereas the enlarged pair of spines of Euphausiids arises by hypertrophy of one previously undistinguished pair among the multiple larval spinules, and does not seem especially significant.

Brooks (p. 202) says of *Anthracophausia* that "The generic name . . . is most appropriate as far as superficial resemblances to the Recent euphausids are concerned. Peach . . . presented reliable evidence that the carapace was not fused with the posterior thoracic segments, but this primitive characteristic is to be expected of the ancestral euphausids. Most disconcerting, however, is the presence of a marsupium on females of the closely related contemporaneous fossil *Crangopsis* . . .". One might go further and say that if oöstegites were in fact present in these genera, their members seem most unlikely to have been ancestral to the Euphausiids or Peneids; and that they ought to be

regarded as primitive Peracarida (in the manner of Calman, 1909, p. 181).

(b) Brooks gives no reason why the Peneids should be thought to have arisen directly from Pennsylvanian Eocaridacea, independently both of the Euphausiids and of the other Decapods. Presumably, he was influenced by the remarkably *Peneus*-like outline and posture of the pleon in *Anthracophausia* (pl. 48). However, the intestine of *Anthracophausia* is shown by his photographs to have run along the middle of the pleon, rather than at the dorsal third as in Euphausiids or above the dorsal fifth as in Peneids and other Decapods. The position of the intestine relatively low in the body presumably indicates that the pleonic flexor muscles of *Anthracophausia* were not enlarged relative to the extensors; hence, that the organization of its pleon was more like that of Lophogastrid Mysidacean Peracarida than of the back-jumping Eucarids.

(c) The only Pygocephalomorph feature which Brooks specifically states to be like that of Eryonids is a sternal structure on the last thoracic somite of presumptive females of *Anthracaris* which "is reminiscent of the sperm receptacle of the syncarids and eryonid decapods" (p. 184). However, as pointed out by Andrews (1911), Eryonids do not have a sperm receptacle; instead, a pair of spermatophores is applied by the male to the surface of the hinder sternites of the female (mistaken by Geoffrey Smith for a receptacle like that of Recent Syncarids). Brooks regards the mandible of *Anthracaris* as "characteristic of decapods" in having a second articulation hinging it to a strongly developed epistome (pp. 181, 183, 265); but according to Snodgrass (1951, pp. 23, 41, 44-5, 46; 1952, pp. 182-3), a double-hinged mandible and a well-developed epistome are characteristic also of Peracarids and Hoplocarids. The resemblance of *Anthracaris* to Eryonids in habitus is surely convergent, since its free thoracic tergites are obviously pre-Eucarid, whereas the Eryonids are specialized chelate Reptants, not even primitive among Eucarida Decapoda Pleocyemata (the stem-form of which was almost certainly natant).

Consequently, paleontological evidence of Eucarid polyphyly is in fact completely lacking. What is instead to be deduced about the ancestor of the Euphausiids and Decapods from the characteristics of the available Paleozoic Eumalacostraca is as follows: It seems most unlikely that any of the ancient forms with reduced, depressed or heavy carapace, reduced or permanently flexed pleon, oöstegites, uniramous or raptorial legs, or a sperm-receptacle, could have given rise to the Eucarids. The three known Devonian genera seem to have lacked all these specializations, but seem in this to have been primitive, generalized Eumalacostraca showing little to connect them more closely with one rather than another of the extant superorders. Syncarid, Peracarid, Hoplocarid and possibly Pancarid specializations are all known in the Mississippian; and it would not be too surprising if a marine shrimp of similar date should ultimately be found, which had developed the definitive Eucarid specializations. Of the relatively unspecialized ancient forms, the one perhaps closest to such a direction of development might be *Palaeopalaemon,* which has carapace sculpture suggestive of that both of Mysids and of Decapods. The extremely hypertrophied antennular peduncle of *Palaeopalaemon* is, however, a specialization which seems to disqualify it as a direct ancestor of the Eucarida.

Brooks's restoration of *Palaeopalaemon* (pl. 9, fig. a) shows a system of carapace grooves resembling those of the Recent Mysid *Anchialina typica.* The groove marked "cvg" in the restoration ("cervical groove", p. 170) appears on Brooks's beautiful photographs (pl. 50, fig. 5; pl. 51, fig. 2) as deep and narrow, faintly turning to the dorsum at its upper end. Just below and parallel to it is a longer ridge, separated from it by a shallow trough which reaches the dorsum behind the middle of the carapace. The groove shown in the restoration as running in a rostral direction from a mid-lateral junction with "cvg", anterior to the level of an excavation of the dorsum, might be the homologue of Boas's groove *d* in Decapods (*cf.* p. 8 below). The dorsal notch might mark Boas's groove *e,* the cervical in the sense of Glaessner (*cf.* Brooks's pl. 14, fig. C, of a Recent Lophogastrid, where the groove marked "cvg" is the one described by Glaessner, 1960, p. 43, as "the last transversal furrow of the Mysidacea . . . [which] extends backward in a narrow U-shaped loop . . . [and] is undoubtedly homologous with the

branchio-cardiac groove of the Decapoda." Brooks's "cvg" in *Palaeopalaemon* might be equivalent to the "intermediate transverse furrow" which Glaessner notes for the Recent Lophogastrid *Eucopia* and evidently regards as homologous with Boas's groove *c,* the post-cervical of Decapods). Although the homologies cannot be regarded as certain, it would seem possible to derive the quadruple system of dorsum-attaining carapace grooves (*a, c, e, d*) which can be postulated for the stem-Eucarid from something like that in *Palaeopalaemon.*

The sharply-marked, midlateral, longitudinal ridge of the carapace of *Palaeopalaemon* is of special interest, because of the suture along its crest which is suggested by Brooks's photographs (pl. 50, fig. 7 and 51, fig. 3). If this suture existed in life, it would suggest that the midlateral ridge of *Palaeopalaemon* might be homologous with the unridged longitudinal suture which is found scattered in a few Recent Peneids, one Recent Eukyphid and many Recent Reptants of various sections (linea thalassinica, l. anomurica, l. homolica).

It is worth special note that Brooks (pp. 221, 258-9, 260) finds *Palaeopalaemon* unusual among available Paleozoic forms both in having had a somewhat calcified exoskeleton and in having been fully marine (*cf.* end of next section).

2. *Permian:* In the early (or early-Middle; or middle Upper) marine Permian (Sosio beds of Sicily; *cf.* Gignoux, 1950, and Neaverson, 1955; but note Montanaro Gallitelli, 1956, pp. 878, 882) Brooks recognizes a Decapod. He says, "the only Paleozoic fossil that may be a true decapod is *Palaeopemphix sosiensis* . . . and related species. . . . The carapaces figured by Gemmellaro . . . have cervical, post-cervical, and branchiocardiac sulci comparable to those of *Pseudoglyphea spinosus* and *Pseudopemphix albertii* . . . from the Triassic . . ." (pp. 269-70). On p. 274, he goes farther and assigns *Palaeopemphix* to the Glypheidae (which were almost certainly definitive Reptants closely related to the Recent Homaridea and Palinuridea).

In my opinion, Brooks's identification in *Palaeopemphix* of a post-cervical sulcus (groove *c* in the notation of Boas) is incorrect, and *Palaeopemphix* is a peculiar form with no close relation to the Glypheids or any other Reptant. However, I believe him to be right in assigning Gemellaro's genus to the Decapoda; on the grounds that it has a cardiacobranchial sulcus reaching the dorsum near the posterior margin of the carapace (groove *a* or *o* in the notation of Boas), and that the posterior margin of the carapace has the dorsal concavity characteristic of Eucarids.

What Brooks presumably regards as a cervical sulcus extends anterodorsally from the middle of the side on to the short rostrum of *Palaeopemphix,* and appears to represent the complete, primitive form of Boas's groove *d.* A complete groove found in the Triassic *Pemphix* anterior to *e* (but crossing the dorsum far posterior to the rostrum) is identified as *d* by Glaessner (1960, fig. 19, 4), but this primitive Palinuran Reptant has so many sulci that their homologies are unclear. In a few Recent Euphausiids, Peneids and Eukyphids (*e.g., Euphausia, Haliporous, Glyphocrangon*), a groove identifiable as *d* runs anterodorsally from a midlateral origin on the cervical to the rostrum, somewhat as in *Palaeopemphix.*

What Brooks evidently considers as the "post-cervical" of *Palaeopemphix* seems to be Boas's groove *q* or *e* (the cervical); not *c,* which according to Gemmellaro's figures seems to be missing. The deep, oblique groove (*a*) which runs from below the juncture of *d* and *e* to near the posterodorsal margin of the carapace (where it crosses the dorsum) resembles the cardiacobranchial of *Haliporus* (the Recent Peneid which seems in several respects the nearest of these to the stem-form of the relatively primitive suborder Dendrobranchiata); except that the cardiacobranchial of *Haliporus* sends off a posteroventral branch (as well as groove *c*). The extreme posterior crossing of the dorsum by groove *a* in *Palaeopemphix* is particularly reminiscent of *Haliporus* (and some species of the related *Hymenopeneus;* as well as the Reptant *Thalassina*). It is not exactly matched by any of the forms of groove *a* diagrammed by Glaessner (1960).

A number of Gemmellaro's specimens are figured as with a tubercle between *d* and *e,* and another behind *e.* These (although also reminiscent of, *e.g.,* the Pygocephalomorph *Anthracaris*) might be homologous with the postorbital spine characteristic of all

Solenocerine Peneids as well as some Sergestids and the Triassic-Jurassic *Aeger,* and with the postcervical spine found in a few Recent Solenocerinae.

The short, high carapace of *Palaeopemphix* and the absence of groove *c* seem surprisingly specialized for a primitive Decapod; although its short rostrum, complete groove *d,* groove *a* crossing the dorsum near the posterior margin, and postorbital tubercle might be primitive Decapod features (the whole peculiar combination requiring taxonomic distinction, which is here instituted by proposal of PALEOPEMPHICIDAE, new family). If the longitudinal ridge of *Palaeopalaemon* and the longitudinal sutures scattered among the Recent Decapoda are in fact homologous, as here suggested, *Palaeopemphix* seems disqualified as the stem-Decapod by loss of the suture. I would guess that when its pleon and appendages become known, it will prove to have been an achelate, calcified, benthonic offshoot of the hypothetical natant stem-Decapod.

Since it is here suggested that there was a varied fauna of Eucarids in the Paleozoic, culminating in the differentiation of the two Pleocyemate supersections of the Decapoda before the end of the Permian, the question arises why the only available traces of such a fauna are the somewhat debatable carapaces of *Palaeopemphix* (when, in contrast, a number of upper Paleozoic non-Eucarid Eumalacostraca are known, as well as a variety of Ostracods, Trilobites and other aquatic arthropods). Brooks has pointed out (1957, pp. 895-6; 1962, pp. 258-262) that marine arthropods with unmineralized exoskeletons are not, under usual conditions, likely to remain intact long enough for fossilization. Fresh- and brackish-water forms, such as the majority of known Paleozoic Eumalacostraca, are more frequently exposed to catastrophes (floods and sudden silting; drying-up and hypersalinity of lagoons; anaerobic conditions brought about by influx of organic material, stagnancy or stratification of water-layers; etc.) which enhance the likelihood of preservation of uncalcified kinds. Natant Crustacea are unlikely to have heavy shells. Scarce forms have (*ceteris paribus*) correspondingly less probability of being preserved than do abundant ones. There are several reasons (indicated at the end of Section IIB2 and in Section III below) for thinking that the Paleozoic Eucarida were, like the Recent ones, preponderantly uncalcified, shrimp-like, marine forms; and it also seems possible that, until the capacities latent in the Eucarid type of organization had begun to be successfully realized through the evolutionary accumulation of further specializations, no dense populations were produced (especially, not benthonic ones, so long as sea-bottom niches were still occupied by long-adapted Trilobites). As regards the frequent fossilization of marine Trilobites and Ostracods in the later Paleozoic, Brooks (1957, p. 896) points out that they "possessed exoskeletons fortified with calcium carbonate. . . ." Likewise, Harrington (1959, pp. O43, O76, O85) states that "The exoskeleton of trilobites consists both of hard mineralized integument and comparatively soft chitinous parts. . . . Ventral appendages of trilobites are very rarely preserved. . . . Parts of the integument were mineralized and hard. . . . This mineralization gave a high rigidity to the test, rendering it easily fossilizable". Benson (1961, p. Q56) says that "pelagic Ostracodes are rare as fossils", and Scott (1961, p. Q21) says that the carapace of ostracods "is composed of two parts: (1) a hard layer of calcium carbonate, and (2) a soft layer, the epidermis. The hard shell substance is preserved in fossils. . . ." Thus, scarcity of Paleozoic Eucarid fossils is conclusive evidence only against abundance of calcified kinds.

B. *Mesozoic:*

1. *Triassic:* The phylogeny of the Mesozoic Decapods has recently been discussed from a paleontological point of view by Glaessner (1957, 1960). Balss (1957) treats the fossils along with the Recent Decapods, and Balss and Gruner (1961) give a paleontological and phylogenetic summary.

Remains of only a few Decapods have been found in the Lower Triassic or Permo-Trias. Two species are referred to the genus *Antrimpos,* some members of which are thought to be very closely related to the recent Peneine *Peneus* (*cf.* Burkenroad, 1936, p. 127, on the Upper Jurassic *Atrimpos speciosus*); indeed, Balss (1922, p. 131) places the Lower Triassic species *atavus* in "*Penaeus*" with the statement, "mit Sicher-

heit hiergehört". In a lower Triassic setting, *Antrimpos* cannot be regarded as primitive; since the Peneinae have undoubtedly evolved from the upper end of a Solenocerine lineage, the lower end of which must have differentiated from a stem which also gave rise to the very primitive Aristeinae; and since this stem seems to have evolved from a common ancestor with the Sergestids, probably resembling *Aeger.* Thus, even without considering the differentiation of the ancestral Dendrobranchiate from the probably achelate, petasma-lacking, appendix-interna-bearing stem-Decapod, an early Triassic Peneine Peneid implies a long series of Decapod predecessors.

A second early *Triassic* form is referred to the Glypheid genus *Litogaster* (with a question mark by Glaessner, 1929; but without a question by Balss and Gruner, 1961). If it is indeed a Glypheid, it is presumably a Reptant Decapod; and evidence from the Recent unequivocally indicates that the Reptantia must have differentiated not only after separation of the incubatory Decapoda Pleocyemata from the Dendrobranchiata, but after separation of the Pleocyemate Natantia from the lineage that later gave rise to the Reptantia. This is shown by the combination of specializations accompanying the benthonic habit in all Recent Reptants (reduced first pleonic somite overlapped by the pleurite of the second when that is expanded; loss of exopodite of the first pleopod, loss of pereiopodal exopodites, etc.; and especially, loss of pleurobranchs anterior to the fifth thoracic somite), which must in all probability have been established in a common ancestor before subdivision of the group, rather than by convergence afterwards. The reason for thinking that the Natant group of incubatory Decapods (Stenopodida and Eukyphida) must have branched off before the definitive Reptant specializations were established is that the Natantia not only have pleurobranchs anterior to the second leg as adults but develop them before the arthrobranchs as larvae (*cf.* Burkenroad, 1939, pp. 316-8). Thus, if the Glypheids are Reptantia, they are not primitive Decapods.

A third early Triassic form is *Clytiopsis,* with two species, classed as a primitive and extinct but Homaridean Reptant group by Balss (1957, pp. 570-1, fig. 1164); the related *Protoclytiopsis* has recently been described from the Permo-Trias of Siberia. It is the present view that the Homaridea must have been derived from an achelate stem, so that *Clytiopsis* cannot even be regarded as primitive among the Pleocyemata Reptantia. Glaessner (1960, p. 48) groups the Homarids with the Peneids (and Stenopodids), citing Beurlen as having shown that the "three pairs of chelate legs in the Trichelida . . . could not have been acquired by primarily benthonic forms"; but against this view that the third legs would have to be reserved exclusively for walking, one might argue that the Eryonids could not have arisen from the achelate Glypheids through *Pemphix* (as proposed by Glaessner, 1960, fig. 19) without benthonic development of chelae on *all* walking legs, not merely the first three. Also, the number of true chelae among Recent Homaridea varies from one pair to four or five, and, as will be shown in the forthcoming review of Recent Decapods, chelae seem to have been independently developed by Eumalacostraca on numerous occasions and on various thoracic appendages including the second and third. Chelae must therefore be regarded as a feature highly subject to convergence, and the wide variation in number of them among different Pleocyemata strongly suggests that the stem-forms both of this suborder and of its supersections had none. A comparison of Glaessner's figures 18 and 19 (1960) shows a remarkable similarity in carapace between the trichelate Triassic Homarids and the achelate Glypheids, consonant with the present suggestion that these two groups are closely related to each other, rather than the Homarids to the Peneids (which have a quite different style of carapace sculpture).

Although I concur fully in Glaessner's observation (1960, p. 36) that "the paleontologist contributes one criterion of incontestable significance, the appearance of various taxa in time . . .," it has to be emphasized that the date of a fossil fixes only the minimal age of the taxon represented, leaving open the possibility that it had differentiated much earlier. The (somewhat questionable) evidence supplied by *Palaeopemphix,* combined with the degree of divergence among early Triassic forms, leaves little room for doubt that direct evidence of the primary evolution of the major

Decapod subdivisions has to be sought in the Permian.

In the Middle Triassic, in addition to further Glypheids and Erymaid Homaridea, the Glypheid-like *Pseudopemphix* and the Palinurid-like *Pemphix* have been found (*cf.* Balss, 1957, pp. 1562, 1577), both with rudimentary chelae. Glaessner (1960) shows that there would be no great difficulty in deriving the carapace of *Pseudopemphix* from that of the Glypheid *Litogaster,* that of *Pemphix* from *Pseudopemphix,* and that of Upper Triassic Eryonid Palinuridea from *Pemphix* (note that the fact that *Pemphix* had begun to develop chelae would seem to exclude it from the direct ancestry of the Scyllarid Palinuridea, despite its resemblance in habitus to the more primitive of the latter).

The Middle and the Upper Triassic yield remains attributed to the peculiar shrimp *Aeger,* which is shown by beautifully preserved late Jurassic material to have been a Peneid, not a Stenopodid. In addition to its three pairs of chelate legs (the third longest, but not stouter) and its first pleonic pleurite overlapping the second, Balss reports a petasma (1957, p. 1559), and I have been able to determine that the pleonic hinges are of a pattern characteristic of Recent Peneids (exposed condyles at the first two and the last two articulations, and a pleurite-covered but well-developed condyle at the third articulation). It is, however, a most peculiar form, as pointed out by Burkenroad (1936, pp. 1-2; 1945, pp. 562, 579). The absence of hepatic spine in most species, the usual presence of a postorbital spine, the ventral tooth of the rostrum, the densely pubescent integument etc., variously suggest Recent Aristeinae, Solenocerinae and some Peneinae; whilst the hypertrophied third maxillipeds and the dorsally-unarmed rostrum suggest certain Recent adult or larval Sergestids. The somewhat reduced first pleonic somite is unlike that of any Recent Dendrobranchiates but comparable with that of the peculiar Upper Jurassic *Acanthochirus* and *Dusa* as figured by Balss (1922). This mixture of characteristics in *Aeger* suggests that its lineage goes back to the undifferentiated Dendrobranchiate stem; and the new family AEGERIDAE is herewith proposed for it. It almost certainly cannot be derived from Peneinae such as *Antrimpos,* although the latter could be derived from something like a generalized form of it. The order of occurrence of the earliest known fossils of *Antrimpos* and *Aeger* thus appears to be the reverse of that in which their lineages differentiated.

2. *Jurassic:* From the Lower Jurassic, there has been reported a variety of Pleocyemate groups not known from the Triassic. These include Eukyphida, Mechochirid Glypheids, Axiid Thalassinidea, Scyllarid Palinuridea, Pagurid (and possibly the Galatheid) Anomala, and Dromiacean Brachyura; as well as a peculiar genus, *Uncina,* which Balss (1957, p. 1560) classifies (after Beurlen and Glaessner, 1930, p. 52) as the Natant "Tribus Uncinoidea . . . Den Stenopodidea nahestehend". What are indicated as unquestionable remains of Galatheids, the Thalassinid *Callianassa* (sensu lato) and Eukyphids have been found later in the Jurassic, strengthening the identifications of less well-preserved Lower Jurassic finds referred to these incubatory sections.

Evidence from the Recent indicates that the Anomala (of de Haan and Boas, comprising the Pagurids, Galatheids and Hippids and excluding the Dromiacea and the Thalassinidea, one or the other of which has customarily been included under the name Anomura H.M.-E.) constitute a monophyletic taxon (antennular stylocerite, peculiar antennal region of the carapace, posterior part of longitudinal suture low on the carapace, reduced fifth leg, medially placed aperture of antennal gland, no podobranchs, etc.). The presence of differentiated Paguridsand Galatheids in the Lias would thus mean that the definitive stem of the Anomala had arisen earlier, presumably in the Triassic.

The Lower Jurassic Scyllarid Palinuridea are presumably derived from an achelate ancestor, therefore perhaps from a time before the appearance of rudimentary chelae in the middle Triassic *Pemphix.* It must be granted that chelae can be lost as well as gained (as shown by, *e.g.,* the aberrant Sergestid *Lucifer* and by Pandalid Eukyphids; in which, however, the retrogression has been accomplished by loss of the dactyl); and Recent Scyllarids have a more advanced development of the diagnostic Palinuridean specialization (the thoracic condyle that en-

gages a depression on the underside of the carapace) than do the Eryonids, as well as various other marked peculiarities such as fusion of the basal joint of the antenna with carapace and epistome. Nevertheless, it would not be surprising to find a primitive achelate Scyllarid, resembling *Pemphix* in habitus, earlier in the Triassic than the Eryonids.

Derivation of the Axiids, in the Lower Jurassic, as "direct descendants of the extinct Glypheocarida" (Glaessner, 1960, p. 48), is at first glance plausible but seems to create phylogenetic difficulties. The distribution of adult and larval characteristics among Recent Thalassinidea suggests that the Axiids (without linea thalassinica), the Callianideids (some with remnants of the linea) and the Callianassids (with linea) had an ancestor with two pairs of chelae, appendices internae and a suture on the carapace; and that this group arose from a common ancestor with the Recent series comprising *Thalassina,* the Laomediids and the Upogebiids, which have a suture although no appendix interna, and have developed only one pair of chelae or none at all (*cf.* Gurney, 1938, pp. 339-343 and 1942, p. 240). It thus seems likely that the achelate ancestor of the Jurassic Axiids had a linea thalassinica, which would exclude the Glypheids. The latter (which are placed close to the Thalassinidea by Balss, 1957) might well be an early, calcified offshoot of the uncalcified, achelate Thalassinid-like Reptant stem, paralleled later from the same stem by the chelate, superficially Homaridean-like Axiids rather than ancestral to them. Such a possibility cannot be dismissed as improbable in the lack of sutured fossils, because the great Tertiary abundance of Callianassid remains consisting almost exclusively of major chelae shows that uncalcified, sutured, achelate Thalassinid-like forms would have had infrequent chances of fossilization. It is therefore here suggested that fossil stem-Reptants have not been found, that Recent Thalassinids have diverged only gradually and incompletely from this stem; and that the fossil Reptants have been preserved because they had become calcified (a specialization with which was correlated a loss of the longitudinal suture).

The Lower Jurassic Brachyuran (*Eocarcinus*), a Dromiacean in which the pleon is "relative gut entwickelt, nicht unter den Carapax geschlagen" (Balss, 1957, p. 1601), may nevertheless in certain respects be less conservative than some of the forms found later in the Jurassic (*e.g.,* it lacks vestiges of the uropods; and according to the present view that the linea homolica is probably homologous with the linea anomurica and the linea thalassinica, it has lost this primitive feature). The distinctive characteristic of the higher Brachyura (loss of arthrobranchs behind the first leg) is foreshadowed in Recent *Dromia,* which still develop posterior arthrobranchs, by a peculiar delay in the appearance of these during ontogeny. Therefore, although Gurney's view of the derivation of the Dromiacea seems sound (1942, p. 270: "it is probable that . . . the Dromiacea sprang" from a stock represented by Recent Laomediid and Upogebiid Thalassinidea), his disagreement with "the general conviction that the Brachyura are descended from the Dromiacea" and his opinion that "the Dromiacea should be excluded altogether from the Brachyura" seem to overemphasize the primitive ontogenetic features of these crabs. In contrast, although exception is here taken to Glaessner's view (1960, fig. 19, p. 45) that the connection of *Eocarcinus* with the unsutured *Pseudopemphix* (classed by Balss, 1957, p. 1577, as a Glypheid) is "beyond doubt", his statement that "It seems to have taken the Brachyura the long span of Jurassic time... to consolidate their organization on the level of the Dromiacea" appears to describe a fact (since the higher Brachyura of the Cretaceous must have had calcified ancestors, the lack of Jurassic traces of which would be inexplicable).

Uncina from the Lower Jurassic is believed by Balss (*l.c.*) to have been near the Stenopodida, but if its first chelipeds were the largest and its enlarged second pleonic pleurite overlapped the reduced first segment, it sounds more like an aberrant Homaridean which had lost the uropodal diaeresis like some Recent *Nephropsis* (as also suggested by the presence of chelae on its fourth and possibly on its fifth legs, described by Beurlen, 1928; *cf.* the multichelate Recent Homaridean *Thaumastocheles*).

The Solenhofen quarries have supplied a marvellous array of thin-shelled Upper Jurassic shrimp, among which *Udorella* is of especial interest to the present discussion. This form, as reconstructed by Balss (*cf.* 1957, fig. 1131), evidently had a pleon with expanded second pleura widely overlapping the large first somite, and with strong condyles exposed at the first two and the last two pleonic articulations but none at the third. Such a pleon is characteristically Eukyphid. In contrast to all Recent Eukyphida, however, *Udorella* had all five pairs of legs subchelate (like the middle six thoracic endopods of the Mysidacean *Eucopia*) instead of having the last three pairs simple and the first two chelate or, as in Crangonoids, the second pair chelate and the first subchelate. The presence of long exopodites on all the legs, and the unreduced first pleonic somite, demonstrate that *Udorella* can not have been a Reptant (despite its resemblance in habitus to the Recent Thalassinid *Naushonia; cf.* Chace, 1939 and Thompson, 1903).

As has already been indicated in Section II, B, 1 above, the fact that the Eukyphida must be derived from an ancestor with pereiopodal exopodites, unreduced first pleonic somite and biramous first pleopod, and with pleurobranchs on the second through eighth thoracic somites, means that they are derived from an incubatory lineage that had not yet developed definitive Reptant characteristics. The Eukyphid (and Stenopodid) line must therefore have already been separated from the Peneid and the Reptant lines at the start of the Mesozoic; despite the lack of any record until the Jurassic. It seems possible that the ancestors of *Udorella* never had chelae (and that the first legs of Recent Crangonoids are also relics from the Permian).

All of the major Recent Eucarid taxa except the Stenopodida and the Euphausiacea (which are not known at all as fossils) are represented in the Jurassic; but comparison with the Recent suggests that the Jurassic representation may be strongly biased toward forms fossilized because they had developed calcified arms and (or) armor. The Eucarid group with the greatest Recent population-mass is the Euphausiacea; and next most abundant (in biomass) are very probably the ancient, natant groups Dendrobranchiata and Eukyphida. Even though it includes so exceptional a deposit as Solenhofen, the available Jurassic record hardly suggests enormous success for these primitive, uncalcified adaptations; yet the strong persistence of bottom-living though natant Peneids and Eukyphids into the Recent despite the increasing pressure of radiation of the Reptantia surely implies a great predominance of such unarmed and unarmored forms in most niches of the Jurassic seas. By analogy, the known Triassic and Jurassic Reptants may have been those relatively scarce but readily fossilizable offshoots which had developed from a persistently abundant, uncalcified Reptant stem-lineage, by way of repeated, independent steps toward the hard-shelled, pincer-armed adaptations conducive to free-ranging benthonic survival in a world of predatory vertebrates.

The sutured ancestors of the Anomala and the Brachyura probably arose in the Triassic from the same conservative, unarmed and unarmored Reptant lineage that had earlier given rise to the calcified, unsutured Glypheids from which the Homarids and Palinurids arose; presumably by way of the habit of carrying shelter with them in forays for food out of reach of their crevices (a habit that would favor modification of the posterior legs and the pleon). The habits and structure of some of the Recent Thalassinids may be quite close to those of the hypothetical stem Reptant and its conservative descendants from which the Anomala and Brachyura seem to have arisen.

A diagrammatic representation of what seems likely to have been the order and time of appearance of the different Eucarid groups is given in Figure 1. The names there applied to the different taxa are discussed in the account of Recent Eucarida now being tidied for publication, but a brief explanation of the present acceptance of a tripartite subdivision of the Reptantia under the ancient names Macrura, Anomala and Brachyura seems needed here. A more natural grouping might be achieved by separation of the Glypheidea, together with their presumptive early offshoot the Homaridea and their presumptive later offshoot the Palinuridea, as the section Trichobranchida (restricted, from Huxley): forms lacking a longitudinal suture, and with the filaments of the gills arranged on the axis in pairs of

multiple series or in disorder (assuming that the extinct Glypheids would in this feature have resembled their presumptive early and late offshoots). The remaining three Reptant subsections Thalassinidea, Anomala and Brachyura would be grouped together as the section Phyllobranchida (redefined; from Huxley), probably having had a common ancestor (subsequent to the separation of the Trichobranchida) which retained the longitudinal suture and had the gill-filaments disposed feather-like in uni- or bi-serial pairs along the stem. Although the gills of the more primitive members of all three Phyllobranchid taxa have been classed as "trichobranchiae", and although the expansion of the filaments into flattened leaves was evidently developed independently on various occasions (and not only among Reptantia), Huxley's name seems appropriate enough.

Such a grouping of the Reptants into Trichobranchida and Phyllobranchida would have several disadvantages. First, it would constitute a radical departure from all the current classificatory modes; whereas one such departure (the present suborders Dendrobranchiata and Pleocyemata) seems enough to introduce at one time. Second, the traditional name Macrura, dispensed with by Boas in his great revision, keeps being piously restored to use, and might better be anchored in a more or less acceptable, restricted fashion (as by Waterman and Chace, 1960, p. 25) than left unassigned for attempts at revival in the ancient sense by non-evolutionary systematists (as Holthuis, 1955, p. 4). Third, poorly-known or early Reptant fossils could safely be reported as Macrura, when their classification as Glypheids, Homarids, Thalassinids, Trichobranchids or Phyllobranchids would not be assured. Fourth, further hierarchic downgrading of the taxa Anomala and Brachyura would over-cramp the subdivision of these latest-differentiated but highly-successful, numerous and varied groups. Accordingly, Chace has for the present been followed in grouping the long-tailed Reptantia which have normal uropods and fifth legs as the Macrura; with the reservation that their phylogenetic relationships, as indicated in Figure 1, might be better expressed by a different arrangement.

III. Summary of Probable Characteristics of Fossils of the Hypothetical Ancestors of Major Eucarid Taxa

The foregoing discussion of the fossil record of Eucarid evolution has followed the order of that fragmentary selection; but has been written from a view-point largely based on Recent evidence concerning phylogeny. Many of the crucial characteristics are unlikely ever to become known in fossils (even if deposits like the Burgess shale and the Solenhofen limestone should be located in the Carboniferous, Permian and early Triassic). In the present section, therefore, some deductions are offered concerning possibly recognizable features of undiscovered key fossils of the Eucarida, in the order in which they are here presumed to have evolved (Figure 1).

1. It seems likely that the Eucarid stem-form developed from a primitive Eumalacostracan shrimp with four carapace grooves crossing the dorsum and a longitudinal lateral suture, which lacked brood-lamellae and sperm-receptacle. It may have differentiated about as early as did the progenitors of other Recent Eumalacostracan superorders (in the Mississippian). It was probably a fairly large prawn; since if the branchiae of Lophogastrid Mysids are homologous with the body-gills of Decapods (as seems likely), the ancestral Eucarid must have had both these body-gills and podobranchs; and even though its water-pumping system may have been inefficient, so extensive a set of gills suggests a high volume-to-surface ratio for the body. It was probably a strong swimmer (large pleon and pleopods), a weaker walker (adequate but unspecialized thoracic endopodites) and a back-jumper with the intestine placed above the middle of the pleon to give room for enlarged flexor muscles (since use of the uropods for retrograde evasive propulsion, rather than for forward jumping or mere steering, seems a probable correlate of the diagnostic fusion of the carapace to the thoracic dorsum, presumably required for streamlining during rapid backward motion). It seems likely to have been a detritus-feeder (no chelae) which travelled and spawned off the bottom like some Recent Peneids (since the lack of fossils suggests a thin shell). The habitat was probably marine, like that of the great majority of

Recent Eucarids (note that although the nursery grounds of the juveniles of many Peneinae are in the estuaries of the warmer regions, the adolescents of almost all of these return to the sea to mature and spawn. Only a few species of one Sergestid genus have achieved completely fresh-water life. Investigators of crustacean excretion, osmoregulation and ionic balance seem generally to believe that Recent brackish- and fresh-water Eukyphids and Reptants are likewise invaders from the sea; *cf.* Robertson, 1960, p. 335 and Parry, 1960, pp. 360-1).

Features at all likely to be detectable in fossils and to distinguish the Eucarid stem-form from the Eumalacostracan ancestor are: (a) carapace fused to all thoracic tergites; (b) spines, rather than furcal lobes, flanking an unarticulated telson point; (c) coxa distinct from basis of thoracic appendages; (d) intestine fairly high in the pleon.

2. The stem-form of the Euphausiacea probably differentiated from the Eucarid ancestor fairly soon after that arose (perhaps in the Pennsylvanian), by completely abandoning contact with the bottom, as a feeder on suspended detritus, like some Recent coastal forms. Characteristics that might be detectable in fossils and would distinguish the Euphausiid stem from its Eucarid ancestor are (a) thoracic endopods weaker, especially posteriorly, and set closer together; (b) male genital aperture shifted from limb-base to sternite; (c) a branch of the appendix interna of the first male pleopod enlarged as a spermatophore-handling organ; (d) branchiostegite of carapace reduced (in correspondence with loss of the body-gills); (e) reduction of sculpture of the carapace including loss of the postcervical and cardiacobranchial sulci and of the longitudinal suture (the primitive function of which latter was probably as a spring to extend the branchiostegites again, after these had been clapped down to eject foreign matter from the gill-chamber).

3. The stem-form of the Decapoda may have differentiated from the primitive Eucarids early in the Permian, by improved adaptation to scavenging on the bottom. In particular, the gills became wholly enclosed by the carapace, and the maxillary pump greatly enlarged. Features possibly detectable in fossils, which would distinguish the stem-Decapod from both the Eucarid ancestor and the Euphausiid branch are: (a) cardiacobranchial sulcus crossing the dorsum near the posterodorsal margin of the carapace; (b) well-spaced and strong though unspecialized walking legs on the posterior five thoracic segments, with reduced exopodites of which the basal part was not enlarged, and with the coxal exite of the posteriormost thoracic leg completely lost; (c) endopodite of first thoracic appendage greatly reduced, that of the second one reduced and flexed, and that of the third turned forward and not used for walking; (d) intestine high in the pleon (in relation to improved back-jumping); and (e) development of an antennular statocyst with a statolith composed of sand-grains (probably independent of the Syncarid organ; needed for precise orientation in a natant bottom-feeder which has to avoid unexpected grounding during rapidly repeated jumps). The Permian Paleopemphicidae seem likely to have been a calcified offshoot of the early Decapod stem.

4. The stem-form of the Dendrobranchiata probably differentiated from the Decapod ancestor in the middle of the Permian, by specializations of which those likely to be detectable and diagnostic in fossils are: (a) development of small chelae on the first three pairs of walking-legs (used for picking out and seizing small benthos such as annelids, the setae of which might conceivably be recognizable in a fossilized gut); (b) uncoupling of the pleopods of the three posterior pairs, by loss of the appendix interna; (c) shift of the endopod of the first pleopod proximally from the tip of the protopodite, its reduction in the female, and enlargement of the entire ramus in the male to form a spermatophore-handling organ (the *petasma,* not homologous with the Euphausiid organ derived from a branch of the appendix interna, nor with the also independently-modified first endopods in various Reptant Decapods; about which Siewing, 1956, pp. 135-6, 157, 159, seems quite mistaken).

5. The common stem of the Eukyphids, Stenopodids and Reptantia (Pleocyemata) probably differentiated from the Decapod stem during the middle of the Permian, by developing pleopodal incubation (which probably replaced an earlier habit of scattering the eggs by off-bottom spawning; and

so permitted the beginning of Decapod evolution toward completely benthonic life). It is possible that ovigerous setae might be recognized in fossils; otherwise the incubatory stem-form might be hard to distinguish from the stem Decapod.

6. The stem-form of the Eukyphids and Stenopodids (Natantia, sensu restricto) probably arose from the incubatory branch during the Upper Permian, by loss of the hinges at the third pleonic articulation (permitting a humped posture). The diagnostic specialization, delay in development, or loss, of arthrobranchs, would not be detectable in fossils. The more benthonic Stenopodid line probably soon differentiated from the Eukyphids (according to the scarcity of adult or larval diagnostics common to their Recent representatives, and the numerous striking differences between the two). Among features that might be seen in fossils, the early Eukyphids (a) probably retained pereiopodal exopodites and did not develop true chelae for some time (and then perhaps at first only on the second walking-leg), whereas the Stenopodids probably soon lost the pereiopodal exopodites entirely and developed chelae on the first three pairs of walking-legs, with the third pair enlarged (perhaps the first Eucarid weapons); the Eukyphids (b) retained a biramous first pair of pleopods and the appendices internae, whilst the Stenopodids lost the coupling of the pleopods and the exopodite of the first one; the Eukyphids (c) developed expanded pleonic pleura with the second overlapping the first, whilst the Stenopodid pleura remained small (and when at all expanded, overlapped from front to rear); the Eukyphids (d) retained a large first pleonic somite, which in the Stenopodids tended to become reduced; the Eukyphids (e) lost the condyle only at the third pleonic articulation, whilst the Stenopodids lost those of the anterior articulations as well (according to an as yet incomplete survey of the Recent forms).

7. Finally, the stem-form of the Reptantia probably developed the definitive characteristic of that supersection (loss of the anterior pleurobranchs, undetectable in fossils) in the Upper Permian and became specialized but still thin-shelled crawlers on the bottom (probably crevice-dwellers until the evolution of armor, arms and shelter-carrying and fossorial habits). Recognizable distinctions of fossils of the stem-Reptant would probably be (a) strong achelate legs without exopodites; (b) exopodite of the first pleopods lost and the rest not large enough for effective swimming although still coupled by an appendix interna; (c) the first pleonic somite reduced and the second pleonic pleura somewhat overlapping the first; (d) the anterodorsal part of the carapace with spiny longitudinal ridges instead of the simple postorbital spine of the stem Decapod. The earliest offshoot of this Thalassinid-like Reptant stem was probably Glypheid, in the late Permian; and these (like their early derivatives, the chelate Homarids) would be distinguishable by calcification and the loss of the lateral longitudinal suture of the carapace.

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ADDITIONS TO A CATALOGUE OF THE DESCRIBED RECENT AND TERTIARY SPECIES OF *ACESTA* AND *PLICACESTA*

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I. Introduction

In an earlier number of the *Tulane Studies in Geology* (vol. 1, no. 2, 1963), the writer presented a catalogue of the described Recent and Tertiary species of *Acesta,* based upon references collected while preparing the description of *Lima* (*Acesta*) *bullisi* H. E. Vokes. At that time it was noted that since the catalogue was the result of a canvass of the literature it was "quite possible" that some species had been overlooked. This latter statement subsequently has proved to be correct and it is now possible to supplement the previous listing and thus to make it more complete.

The writer is greatly indebted to Professor R. L. Merklin of the Paleontological Institute, Akademy Nauk, U.S.S.R., for calling his attention to the eastern Siberian occurrences of *Acesta* and furnishing a photocopy of an important reference.

II. Additions to the Catalogue of *Lima (Acesta)*

Recent Species

Atlantic Basin Area

Lima (Acesta) angolensis Adam and Knudsen

Lima angolensis Adam and Knudsen, 1955, Bull. Inst. Roy. des Sci. Nat. Belgique, **31** (61), pp. 19-23, pl. 2, figs. 1-4.

Range: The type of this species was dredged at Station 88 of the Belgian Oceanographic Expedition (1948-1949) in the eastern portion of the South Atlantic Ocean off the coast of Angola, Lat. 10°45′ S., Long. 13°07′ E., from 400 to 500 meters depth.

Size: "Dimensions.—Longeur: 153 mm; largeur: 122 mm; epaisseur: 49 mm."

Ecologic information: The bottom sediment at Station 88 is given as being of green sandy mud; the depth, as noted above, 400 to 500 meters. No temperature record was given.

Notes: This species is distinguished from *L. (A.) excavata* (Fabricius) mainly on the presence of a "nodule" at each extremity of the cardinal margin of the right valve received between two elongate, parallel "nodules" on the left. These structures, which are lacking in *excavata,* are described as being "très peu apparents." As illustrated the posterior auricle seems proportionately to be somewhat shorter in the new species than it is in *excavata.* This results in a more broadly rounded posterior dorsal part of the shell.

Tertiary Species

Western Pacific: Eastern Siberia and Sakhalin Island

Lima (Acesta) sakhalinensis Slodkevich

Lima (Acesta) concentrica Khomenko, 1934, Tr. Petrol. Geol. Prospecting Inst. [NGRI], (A) **40**, p. 30, pl. 1, fig. 7 [non *Lima concentrica* Sowerby 1888, Zool. Soc. London, Proc. for 1888, p. 207, pl. 11, fig. 20].

Lima sakhalinensis Slodkevich, 1938, Paleont. USSR, **10** (3), Tertiary Pelecypoda from the Far East, pt. 1, p. 211 (Russian text), pl. 42, fig. 8; pt. 2, p. 113 (English text).

Lima sakhalinensis is described as having the shape of *Lima (Acesta) goliath* Sowerby (1883, p. 30, pl. 7, fig. 3) a Recent species living off the coasts of Japan, and known also (see H. E. Vokes, 1963, p. 87) from the Upper Miocene and Pliocene de-

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posits of the same region. It differs from the Japanese species, however, in details of the ornamentation, possessing only "the finest concentric lines of growth" and "not elevated, gentle, irregular concentric folds bearing the same character as on *Palliolum (Delectopecten) pedroanus* (Trask)." (Slodkevich, *sup. cit.*, p. 113)

The species was described from the Upper Pil Series, Lower Miocene, from North of Cape Pilvo, in the northern part of Sakhalin Island.

Lima (Acesta) new species?

Lima goliath "Smith". Slodkevich, 1938, Paleont. USSR, **10** (31), Tertiary Pelecypoda from the Far East, pt. 1, p. 212 (Russian text, *pars*), pl. 43, figs. 1, 1a (only); pt. 2, p. 114 (English text, *pars*); [*non* pl. 43, fig. 2].

Slodkevich (*sup. cit.*) discusses and figures two large limid specimens from the upper Miocene of Kamchatka. Both are referred to *Lima goliath* "Smith" [= Sowerby], but neither appears to have been identified correctly. The larger specimen, illustrated in his figures 1 and 1a, is a broadly orbicular form which, judging from his illustration has very weakly developed *Acesta*-type radial ornamentation. It appears, to the present writer, to be most like the Japanese Miocene *Lima (Acesta) omorii* Aoki (1956, p. 189, pl. 29, fig. 1; text fig. 2:7), described from Iwati Prefecture in the northern part of Honshu Island.

The smaller specimen has well-developed radial ornamentation preserved on a small portion of the valve and may represent a species similar to *Lima (Acesta) celebensis* Bartsch (1913, p. 240, pls. 18, 19) or, more probably, is a *Lima (Plicacesta)* close to *smithi* Sowerby (1888, p. 207, pl. 11, fig. 12).

Europe: France

Cossmann has described two very small species from the Eocene of the Loire Basin of France which he has referred to *Lima (Acesta)*. Both are too small and too imperfectly illustrated to permit any conclusions as to their systematic position without access to the original specimens. For the present, therefore, they will be tentatively referred to *Acesta,* although with considerable doubt.

Lima (Acesta?) dumasi Cossmann

Lima (Acesta) dumasi Cossmann, 1904, Bull. Soc. Sci. nat. de l'Ouest de la France, (2) **4**, p. 163, pl. 2, fig. 24; pl. 3, figs. 3, 4.

This small species (length 8.5 mm, width 6.5 mm) has an ornamentation similar to that of many species of *Acesta*. The ligamental pit is described, however, as being triangular with the summit "un peu incurvé en avant." This condition, considered in more detail below in the discussion of *Lima iheringi* (Soot Ryen), is not that characteristic of *Acesta*—in the adult stage at least. Furthermore, none of the specimens of *excavata* or of *bullisi* available for examination show any trace of a structure in the immature stages that would be described as having the apex only a "little incurved" in front of the main ligamental mass.

Lima (Acesta?) hyphanta Cossmann

Lima (Acesta) hyphanta Cossmann, 1904, Bull. Soc. Sci. nat. de l'Ouest de la France, (2) **4**, p. 164, pl. 3, figs. 14, 15.

This minute form is known from a single specimen 4.5 mm high and 3.5 mm wide. The general outline is similar to that of species of *Acesta*, but the ornamentation of an "élégant treillis de stries rayonnants et obliquement curvilignes, dont l'intersection produit une multitude de fines ponctuations" seems foreign to this subgenus.

Species Incorrectly Referred to *Acesta*

South America

Acesta iheringi Soot-Ryen

Lima patagonica von Ihering, 1907, Anales Mus. Nac. de Buenos Aires, **14** [ser. 3, 7], p. 262, pl. 9, fig. 60. [*non* Dall, 1902, Nautilus, **16** (2), p. 16].

Acesta iheringi Soot-Ryen, 1959, Lunds Univ. Arsskrift, (N.F.) (2) **55** (6), p. 33. [n.n. pro *Lima patagonica* von Ihering, *non* Dall].

In the earlier paper (1963, pp. 80-81) it was noted that von Ihering's species was a junior homonym of *Lima (Acesta) patagonica* Dall; overlooked, however, was the fact that Soot-Ryen had proposed the replacement name *Acesta iheringi.* No basis is given for the reference to *Acesta*, and in the writer's opinion the form is incorrectly referred to that subgenus (or genus). In the original description von Ihering notes that the anterior auricle is larger than the posterior, whereas in *Acesta* it characteristically is greatly reduced through the encroachment of the excavate lunule. The latter is one of the most noticeable features of the shell, but von Ihering does not even mention the lunule in his description. The reduction of the anterior auricle results in the umbones being essentially at the anterior end of the dorsal margin with the cardinal area almost wholly posterior in position. This has as a further result, the development of a markedly oblique ligamental pit (see H. E. Vokes, 1963, pl. 1, figs. 2, 3; pl. 2, fig. 3). The pit in the Patagonian species was described by von Ihering as follows: "La fossette ligamentaire est

triangulaire, à base plus large que la hauteur et inclinée un peu en dehors." It appears to be wholly different from that characteristic of *Acesta*.

According to von Ihering, his species is similar to *Lima angulata* Sowerby (1843, p. 86, pl. 22, figs. 39, 40) [non *Lima angulata* Münster, 1841], which has been renamed *Lima (Mantellum) orbignyi* Lamy (1930, p. 180). This species is the type, by original designation, of the "section" *Submantellum* Olsson & Harbison 1953 (p. 60). While the original illustration given by von Ihering for his *Lima patagonica* is not at all satisfactory, the details of shape and proportion agree very favorably with the illustrations of *Lima orbignyi* Lamy (*cf.* for example, Olsson, 1961, pl. 17, fig. 3), and the writer is of the opinion that the correct denomination for the species is *Lima (Submantellum) iheringi* (Soot-Ryen).

III. Additions to the Catalogue of *Lima (Plicacesta)*

Lima (plicacesta) sphoni Hertlein

Lima (Plicacesta) sphoni Hertlein, 1963, Calif. Acad. Sci., Occas. Pap. no. 40, p. 3, figures 1-3.

Since the publication of the previous catalogue (H. E. Vokes, 1963), Hertlein has described *Lima (Plicacesta) sphoni* dredged from 457-549 meters (250-300 fathoms) between Santa Catalina and Santa Barbara Islands, California. This, the second Recent species of *Plicacesta*, the other being the type, *L. (P.) smithi* Sowerby, is a much larger form being 114 mm high and 91 mm wide. Sowerby (1888, p. 207) stated that the type of *smithi* was 63 mm high and 51 mm wide; Oyama (1943, p. 45) gives measurements of a larger specimen as 98 mm high and 80 mm wide. The two species also differ in details of shape and ornamentation.

Lima (plicacesta) new species

?, *Lima goliath* "Smith". Slodkevich, 1938, Paleont. USSR, **10** (3), Tertiary Pelecypoda from the Far East, pt. 1, p. 212 (Russian text, *pars*), pl. 43, fig. 2 (only); pt. 2, p. 114 (English text, *pars*).

Lima aff. *goliath* Sowerby. Merklin, 1954, Doklady, Akad. Nauk, USSR, **95** (2), pp. 379-380, text figs. 1, 2.

As noted above, the smaller of the two specimens from the upper Miocene of Kamchatka figured by Slodkevich as *Lima goliath* Smith [= Sowerby] may well prove to be a specimen of *Lima (Plicacesta)*. Another specimen, which possibly represents the same species, was collected in the Anadyra region, south of the Chukotka Peninsula. The figures given by Merklin *(sup. cit.)* show remnants of a relatively thick shell adhering to the incomplete internal mold which appears also to exhibit traces of the radial sculpture, suggesting that the shell was plicate, and hence referrable to *Plicacesta*. This suggestion receives confirmation in a recent letter from Prof. Merklin in which he says: "I think now that this form is rather *Lima (Plicacesta)*."

The species is apparently of large size. Although the original illustration was labelled as being of natural size, and indicated a specimen of approximately 80 mm height with the dorsal margin missing, a reprint kindly furnished by Prof. Merklin bears the notation in ink "⅔", suggesting that the specimen had a height of at least 120 mm. It appears to differ from *L. (P.) smithi* in details of shape, with a longer relatively straight anterior margin and a proportionately broader shell. The ornamentation is too incompletely represented to permit it being compared with that of the Recent species.

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TULANE STUDIES IN GEOLOGY

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THE RACCOON *(PROCYON)* IN THE PLEISTOCENE OF NORTH AMERICA
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A MISTAKEN REPORT OF A PECCARY FROM THE PLEISTOCENE OF LOUISIANA
ANDREW A. ARATA
DEPARTMENT OF ZOOLOGY
TULANE UNIVERSITY p. 28

GEOLOGY OF THE LAVON AREA, COLLIN COUNTY, TEXAS
R. O. STEINHOFF
TULANE UNIVERSITY
ASSISTANT PROFESSOR OF GEOLOGY p. 29

THE GENUS *TURBINELLA* (Mollusca, Gastropoda) IN THE NEW WORLD
EMILY H. VOKES
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CONTENTS

ABSTRACT 21
I. INTRODUCTION 21
II. MATERIALS 22
III. DISCUSSION 22
IV. CONCLUSION 26
LITERATURE CITED 26

ABSTRACT

Three fossil forms of raccoons (*Procyon priscus* Leidy, 1856, *P. simus* Gidley, 1906, and *P. nanus* Simpson, 1929) are considered synonyms of *P. lotor* (Linnaeus), the only species known from the Pleistocene of North America.

Localities from which fossil *Procyon* have been reported are mapped, along with unpublished records of the genus.

I. INTRODUCTION

The earliest known *Procyon* is *P. rexroadensis* Hibbard, 1941, from the Rexroad formation, Meade Co., Kansas. Hibbard (1950; 1954) considers this Upper Pliocene, others (Moore, 1949; Leonard, 1950; Frye and Leonard, 1952) would assign this fauna to Lower Pleistocene. Another specimen (*Procyon* sp.) from Cita Canyon Locality (Johnson and Savage, 1949) may be of a similar age (Moore, *op. cit.*), but again there is no general agreement as to the age of such Blancan faunas.

The remaining North American fossil records of the genus are clearly Pleistocene, and are accommodated under four specific names. Numerous deposits have yielded remains of the extant species, *P. lotor*. The other three, supposedly extinct fossil species are each known from a single specimen. Several references in paleontological literature are to Recent nominal species currently included in the synonomy of *P. lotor* (e.g., *P. psora* as used by Stock, 1918).

Throughout continental North America all Recent raccoons *Procyon (Procyon)* have been ascribed to *P. lotor* (Goldman, 1950; Hall and Kelson, 1959; Miller and Kellogg, 1955). The remaining five species of the

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subgenus are insular. The specific status of at least one of these forms, *P. maynardi* of the Bahamas, has been questioned (Koopman, *et al.,* 1957) and human introduction suspected (McKinley, 1959). Twenty-five subspecies of *P. lotor* are recognized (Hall and Kelson, *op. cit.*).

Considerable geographic variation in both size and color is evident in Recent *P. lotor.* Raccoons are largest in the colder, northern regions and smallest in the south, especially east of the Mississippi River. The largest are found in the Pacific northwest (Stains, 1956) the smallest in the Florida Keys. Stains *(op. cit.)* reports an unusually large female from Meade Co., Kansas, 1180 mm in total length; the mean total length of 4 adult females from the Florida Keys is 688 mm (660 mm-720 mm), only 58 percent of that of the Kansas specimen (Goldman, *op. cit.*). An average total skull length of 102 mm (100 mm-106 mm) of 5 individuals from the Florida Keys contrasts strongly with that of a specimen measuring 145 mm from Colusa Co., California (Goldman, *op. cit.*).

II. Materials

The holotypic material of *P. priscus* (Academy of Natural Sciences, Philadelphia—ANSP 11629 and 11630), *P. simus* (United States National Museum—USNM 2634), and *P. nanus* (American Museum of Natural History—AMNH 2329) were examined. Approximately 100 skulls of Recent *P. lotor* were examined, chiefly in the Recent mammal collections of the University of Florida (UF) and Tulane University (TU).

Florida and Louisiana *Procyon* fossils reported for the first time herein are deposited in the vertebrate paleontological collections of the University of Florida (UF-VP), Florida Geological Survey (FGS) and Tulane University (TU-VP).

The authors express their appreciation to the individuals in charge of these collections for permission to examine specimens in their care. Special thanks are due to Dr. Clayton E. Ray (United States National Museum) for suggestions and constructive criticism during the initial stage of this work at the Florida State Museum.

III. Discussion

Fossil remains of *Procyon* from the unglaciated area of northwestern Illinois near the town of Galena, Jo Daviess Co., were described by LeConte (1848) as a new species of raccoon, *P. priscus.*

The material upon which this form is based is cataloged in two lots that represent what appears to be the remains of a single animal. One lot (ANSP 11629) contains a left mandibular fragment with roots of M_3, a right posterior mandibular fragment (probably the posterior element of a corresponding anterior fragment in the second lot) and 15 elements consisting of five metatarsals and assorted fragments of long bones. The second lot (ANSP 11630) contains left P_3, right C^1, a left maxillary fragment containing P^4 - M^1, and the right anterior mandibular fragment (mentioned above) with C_1 and P_4.

The original text of LeConte *(op. cit.),* an abstract of an apparently unpublished paper presented at a meeting of the Association of American Geologists and Naturalists the previous year (1847), reads as follows: "The author then alluded to a new species of raccoon, *Procyon priscus,* of which several teeth and phalanges have been procured. The differences between this and *P. lotor* are very minute and would not be intelligible

Table I.

COMPARISON OF LENGTH AND WIDTH OF P^4 AND M^1 OF *P. PRISCUS* LEIDY 1856, TO THE SAME MEASUREMENTS IN RECENT *P. LOTOR.*

	P^4 (length x width) (4th upper molar of Leidy, 1856)	M^1 (length x width) (5th upper molar of Leidy, 1856)
P. priscus	9.2 x 9.1 mm	9.9 x 10.6 mm
P. lotor ssp. (TU 619)	9.2 x 9.3 mm	9.9 x 10.9 mm
*P. lotor megalodous** (data from Lowery, 1943)	7.4 - 9.6 x 7.1 - 9.3 mm	7.9 - 10.2 x 8.4 - 10.3 mm

* 39 specimens

without plates." This cannot be considered a diagnosis or description, and the name *Procyon priscus* is here a *nomen nudum.*

Procyon priscus enters zoological nomenclature when Leidy (1856) published illustrations of the fragments bearing teeth and commented that the molars were ". . . the same form as the corresponding teeth of *Procyon lotor,* but are about one sixth larger."

In a large series of *P. lotor* the size of the elements considered to be diagnostic of *P. priscus* may be matched (Table I). Similarly, the supposedly diagnostic characters of the mandibular teeth of *P. priscus* lie within the range of variation of a representative series of *P. lotor.*

Oelrich (1953) stated that *P. priscus* was probably not distinct from *P. lotor* but did not indicate that he had examined the type material and compared it with *P. lotor.* Our examination of the material indicates that *P. priscus* is conspecific with *P. lotor.*

Cranial fragments (USNM 2634) collected in "Cave Bear" Cave, McCloud River, California in 1881 were described by Gidley (1906) as an extinct species of raccoon, *P. simus.* The form was distinguished from Recent *P. lotor psora* of California on the massiveness of the lower jaws, the size of, and breadth between, the upper canines and the more squarely set incisors.

These are, however, essentially the characters of Recent *P. lotor excelsus* of northern California and adjacent Oregon and Nevada. Most of the characters of *P. simus* are concerned with the breadth of the rostrum and depth of the lower jaw, or measurements that are functions thereof, and fall within the range of *P. lotor,* especially *P. lotor excelsus* (see Goldman, 1950; especially plates 6A, p. 117, and 12A, p. 129). Whereas we do not mean to imply that *P. simus* is synonymous with this race *(P. lotor excelsus),* we do feel that the specimen in question is merely a large *P. lotor.*

The premolars are less crowded in smaller, southeastern *P. lotor* than in the holotype of *P. simus,* and the elongation of the mandible of *P. simus* is due chiefly to the distance between the P_2 and C_1. The anteroposterior measurement of P_3 - M_2 is but 33.5 mm, as compared to a mean total length of 34.0 mm (33.6-35.6 mm) for 10 specimens of *P. lotor megalodous,* a rather large-molared Recent raccoon from southern Louisiana.

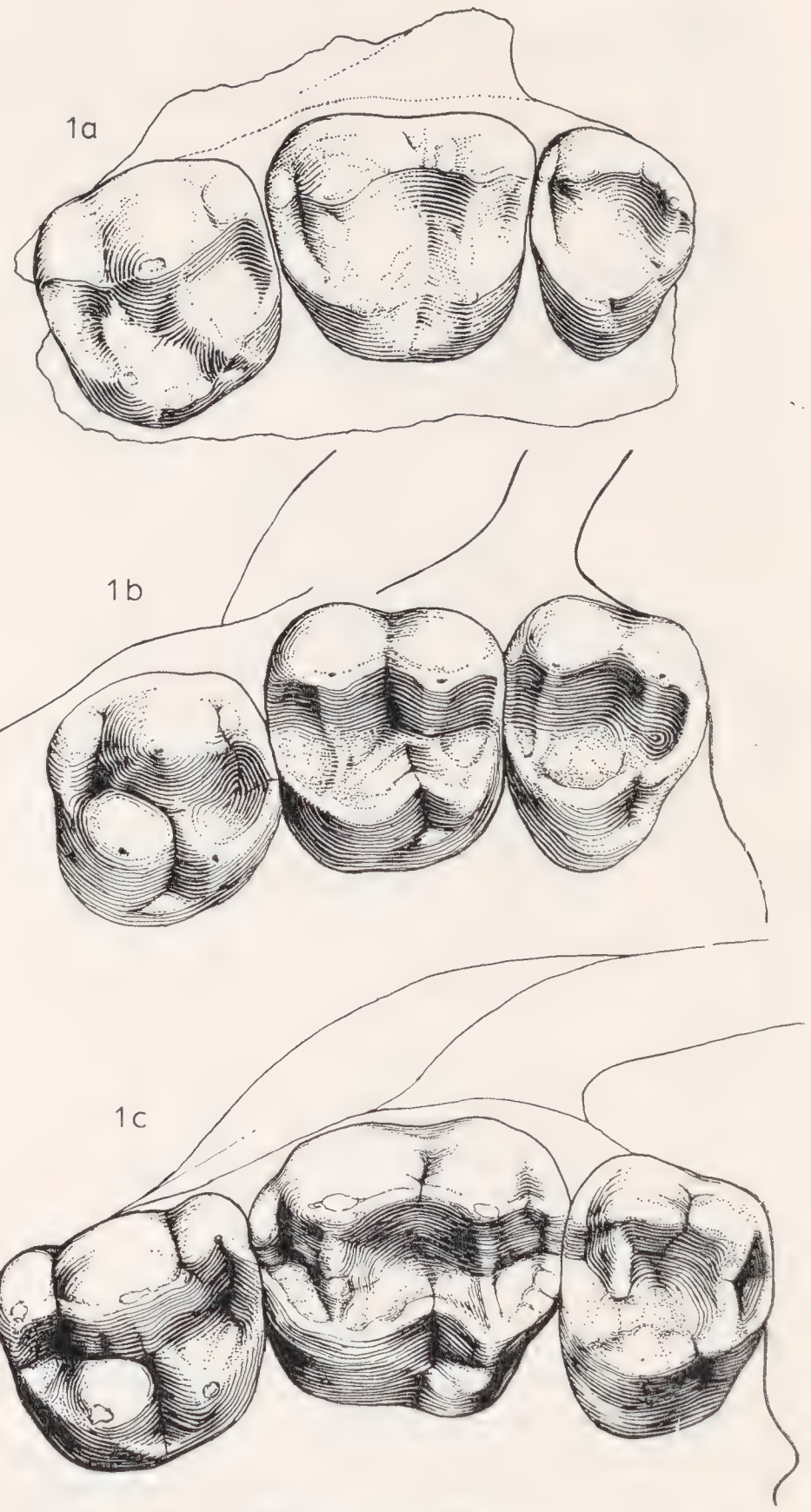

Figure 1a. Holotype of *P. nanus* Simpson 1929, (AMNH 23529) from Seminole Field, Pinellas Co., Fla. (2.6 x)

Figure 1b. P^4 - M^2, *P. lotor,* ad. ♂ (UF 1593), Big Pine Key, Fla. (2.6 x)

Figure 1c. P^4 - M^2, *P. lotor,* ad. ♂ (UF 1915), North Key Largo, Fla. (2.6 x)

Similarly, the second molars, upper and lower, are not relatively larger than are those in some races of *P. lotor.*

Simpson (1929) described a new species of raccoon, *P. nanus,* on the basis of a fragmentary maxilla (AMNH 2329) with three teeth (P^4 - M^2) from Seminole Field, Pinellas Co., Florida. This new form was distinguished from *P. lotor* on the basis of the P^4 - M^2 length, the length-width ratios of the two molars and the vestigial nature of the postero-external cusp of the last premolar.

Examination of a large series of Recent *P. lotor* from Florida and of other *Procyon* specimens from the same deposit (referred to *P. lotor* by Simpson, *op. cit.*) reveals that

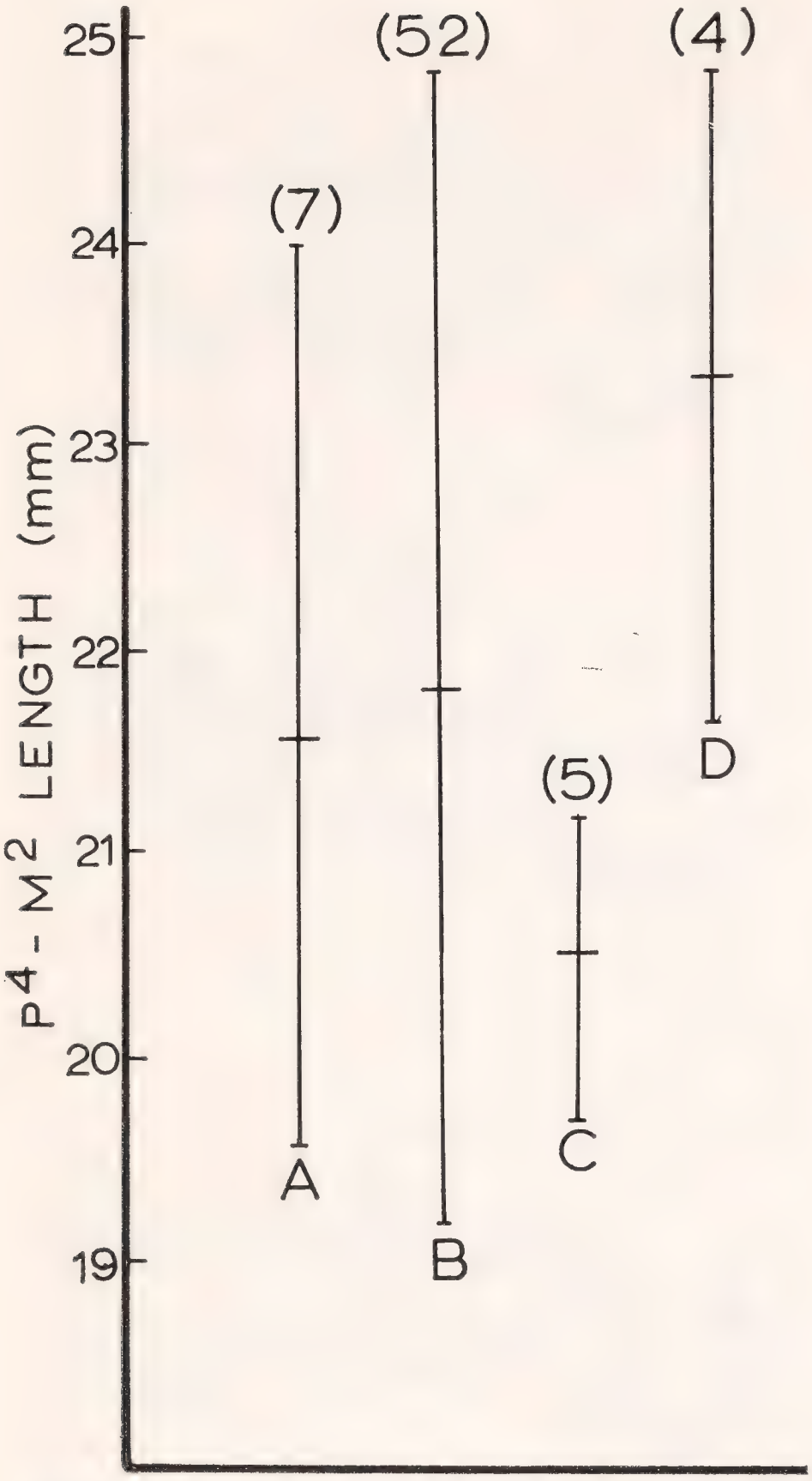

Figure 2. P^4 - M^2 length in *Procyon:* A. Pleistocene *Procyon* from Seminole Field, Pinellas Co., Florida; B. Recent *P. lotor* from Florida (several subspecies included); C. *P. lotor incautus*, Florida, Monroe Co., Big Pine Key; D. *P. lotor marinus*, Florida, Collier Co. (Number of specimens examined in parentheses).

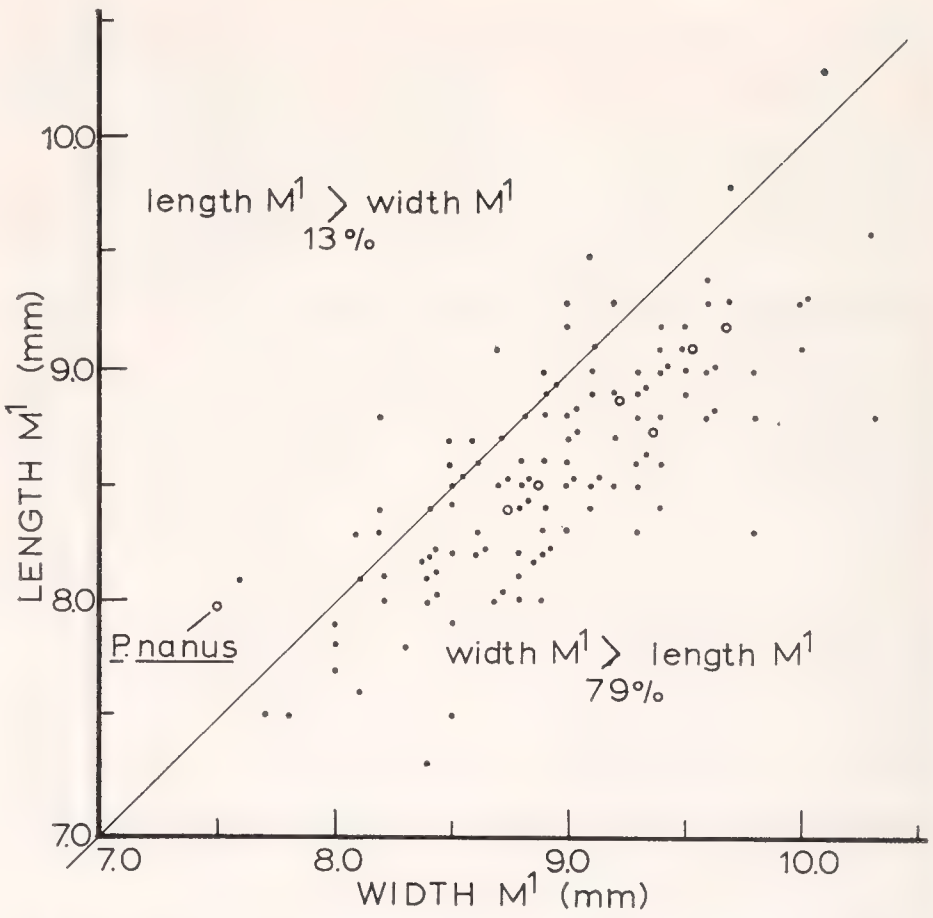

Figure 3. Comparison of length M^1/width M^1 in 120 specimens of Recent *P. lotor* to the same ratio for Pleistocene specimens (open circles) from Seminole Field, Pinellas Co., Florida.

the specimen in question is a small *P. lotor.* The holotype of *P. nanus* (the only specimen referred to this species) is a strikingly small specimen (Fig. 1a). Simpson *(op. cit.)* recorded a P^4 - M^2 length of 19 mm: our measurement of the specimen is 19.6 mm, and was taken in the same manner on all Recent specimens examined. We did not include very young individuals of *P. lotor* in our comparative series, as the alignment of the molariform series is different (more lingually convex) and measurements so taken are not directly comparable to those of older, longer-snouted animals. The smallest Recent individuals (two) encountered measured 19.2 mm, the largest, 24.8 mm; 29% greater than the smallest specimens.

Six of the referred *P. lotor* from Seminole Field are represented by maxillary fragments bearing P^4 - M^2. Grouping these specimens with the holotype of *P. nanus* reveals that the Seminole Field population corresponds closely with a large Recent series from Florida (Fig. 2). Small samples of two of the six recognized Recent races of *P. lotor* are more distinct from one another in this character than is the fossil form when compared to any of the modern races.

The fact that M^1 of *P. nanus* is longer than broad was given as a diagnostic character of the species. Generally M^1 of *P. lotor* is not as long as broad, but this is not the case in all specimens. Combining data on Louisiana specimens (Lowery, 1943) with our measurements of Florida specimens, we find that in 13% (of 120 Recent animals) M^1 is longer than broad (Fig. 3). The ratio (length M^1/width M^1) for 120 Recent specimens of *P. lotor* is 0.85-1.07, mean 0.96. The same ratio for 7 *Procyon* specimens from Seminole Field (including the holotype of *P. nanus*) is 0.93-1.07, mean 0.96. The holotype of *P. nanus* is the only Seminole Field specimen in which M^1 is longer than broad.

The M^2 of the holotype of *P. nanus* is relatively small and narrow, but in this char-

acter is more like many specimens of *P. lotor* than are other specimens of *P. lotor* (Fig. 1b and c). The reduction of M^2 is most often evident in series of the small insular raccoons from the Florida Keys (e.g., *P. lotor incautus*).

All of the characters on which *P. nanus* was distinguished from *P. lotor* can be

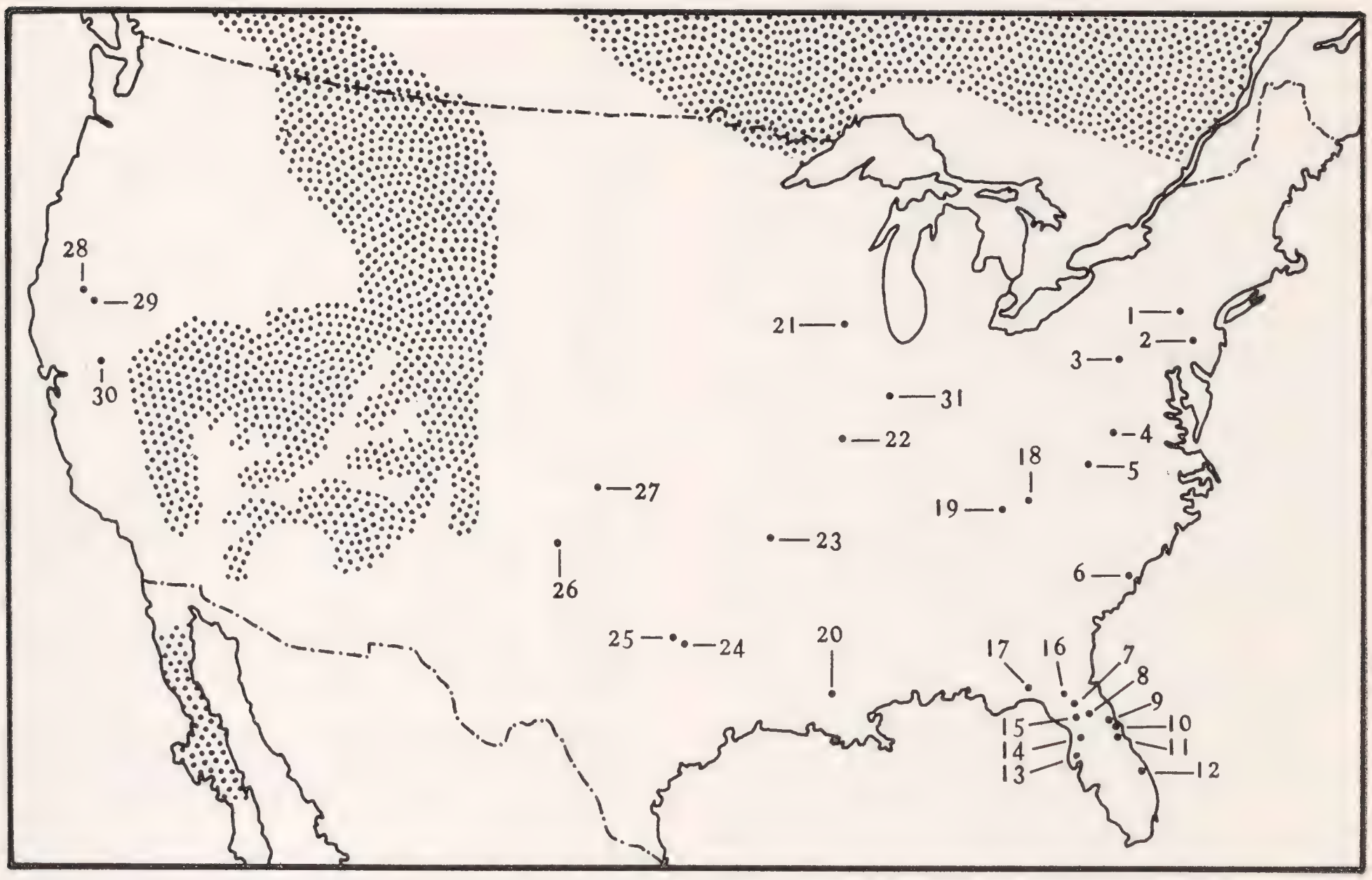

Figure 4. Localities from which fossil *Procyon* have been reported. Citations may be to major bibliographic sources (e.g., Hay, 1923, or Ray, 1957), or to the original reports. Areas in which *Procyon* is not found presently are shaded (after Hall and Kelson, 1959).

1) Pennsylvania, Monroe Co., Crystal Hill Cave (Hay, 1923)
2) Pennsylvania, Bucks Co., Durlam Cave (Hay, 1923)
3) Pennsylvania, Bedford Co. (Guilday and Bender, 1958)
4) Virginia, Augusta Co., Natural Chimneys (Guilday, 1962)
5) Virginia, Wythe Co. (Hay, 1923)
6) South Carolina, Ashley River (Hay, 1923)
7) Florida, Alachua Co., Haile XIIA (this report)
8) Florida, Marion Co., Reddick (this report)
9) Florida, Brevard Co., Merritt Island (this report)
10) Florida, Brevard Co., South Indian Field (Ray, 1957)
11) Florida, Brevard Co., Melbourne (Ray, 1958)
12) Florida, Indian River Co., Vero Beach (Ray, 1957)
13) Florida, Pinellas Co., Seminole Field (Simpson, 1929)
14) Florida, Citrus Co., Bone Cave (this report)
15) Florida, Levy Co., Devil's Den (this report)
16) Florida, Columbia Co., Itchtucknee River (this report)
17) Florida, Wakulla Co., Wakulla Spring (this report)
18) Tennessee, Hamblen Co. (Cahn, 1939)
19) Tennessee, Anderson Co. (Cahn, 1939)
20) Louisiana, West Feliciana Parish, Kimball Creek (this report)
21) Illinois, Jo Daviess Co., Galena (Le Conte, 1848)
22) Missouri, St. Louis Co., St. Louis (Simpson, 1949)
23) Arkansas, Newton Co., Conard Fissure (Brown, 1908)
24) Texas, Dallas Co., Trinity River (Slaughter, et al., 1962)
25) Texas, Denton Co., Clear Creek (Slaughter and Ritchie, 1963)
26) Texas, Cita Canyon Locality (Johnson and Savage, 1955)
27) Kansas, Meade Co., Rexroad formation (Hibbard, 1941)
28) California, Shasta Co., Samuel Cave (Stock, 1918)
29) California, Shasta Co. (?), Cave Bear Cave on McCloud River (Gidley, 1906)
30) California, Eldorado Co., Hawver Cave (Stock, 1918)
31) Illinois, Coles Co. (Galbreath, 1938)

matched within moderate series of the latter (Fig. 1a, b, c), and we have been unable to discover other distinguishing characters. Thus we consider the two to be conspecific.

All other specifically identifiable Pleistocene *Procyon* remains have been referred to *P. lotor,* and are included in at least 20 published Pleistocene faunal lists and probably others not listed here (Fig. 4). Previously unreported records (catalog number or disposition of at least one representative specimen in parentheses) are: Florida, Marion Co., Reddick[1] (UF 8814); Florida, Levy Co., Devil's Den[2] (UF uncatalogued); Florida, Columbia Co., Itchtucknee River, Tributary Locality (UF 2731); Florida, Alachua Co., Haile XIIA (UF 3501); Florida, Brevard Co., Merritt Island (UF uncataloged—Accession Number 50); Florida, Citrus Co., Bone Cave (UF uncataloged); Florida, Wakulla Co., Wakulla Spring (FGS V-4807a); Louisiana, West Feliciana Parish, Kimball Creek, tributary of Little Bayou Sara (TU-VP uncataloged).

Hibbard (1958) lists *P. lotor* only from the Wisconsin, although specimens are also reported from the Conard Fissure, Arkansas (Brown, 1908; Hay, 1924), which he considers to be Illinoian or Sangamon. Subsequently, Slaughter, *et al.* (1962) and Slaughter and Ritchie (1963) report *P. lotor* from two Sangamon deposits in Texas. Most of the remaining records are from cave, sink hole, spring and stream bed deposits generally considered to be late Pleistocene but not assigned to a particular stage (Fig. 4).

No fossil *P. lotor* have been recorded from areas outside of the modern range of the species (Fig. 4).

IV. Conclusion

The first known *Procyon* is *P. rexroadensis* from the upper Pliocene (according to Hibbard, 1941).

Three Pleistocene forms (*P. priscus* Leidy, 1856, *P. simus* Gidley, 1906, and *P. nanus* Simpson, 1929) are included in the synonomy of *P. lotor* (Linnaeus). All North American Pleistocene records of *Procyon* are to this species. The degree of variation in Pleistocene raccoons seems comparable to that observed in the modern animals.

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[1] A paper, recently received, by Gut and Ray (1963) also cites this locality.

[2] This, as well as Itchtucknee and Wakulla, should be referred to as Quaternary.

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PALEONTOLOGICAL NOTE

A MISTAKEN REPORT OF A PECCARY FROM THE PLEISTOCENE OF LOUISIANA

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West Feliciana Parish, Louisiana, is one of the few areas of the state from which Pleistocene vertebrate fossils are commonly reported. Hay (1924) listed the occurrence of mastodon, mammoth and horse from this area. Proboscidean remains are often found in the area but seldom receive notice other than an occasional comment in a local paper. In a study of Pleistocene plant fossils of this area, Brown (1938) reported proboscidean, tapir and peccary (genus indetermined). The probiscidean and tapir were found associated with a flora containing distinctly northern elements (white spruce, larch, and white cedar) assigned to the Peorian interglacial stage of the Pleistocene. Brown (*op. cit.*) noted that the lower jaw referred to as peccary was found "loose in the gravel of the steam bed." The locality was given as approximately 20 miles northeast of St. Francisville, West Feliciana Parish, T. 1 S., R. 4 W., between sections 87-88 and 89-90. The site is on a high stream bank known as Percy Bluff, on Little Bayou Sara, approximately 3 miles south (on state highway 66) of the Post Office at Retreat, Louisiana. The stratigraphy is discussed by Brown (*op. cit.*).

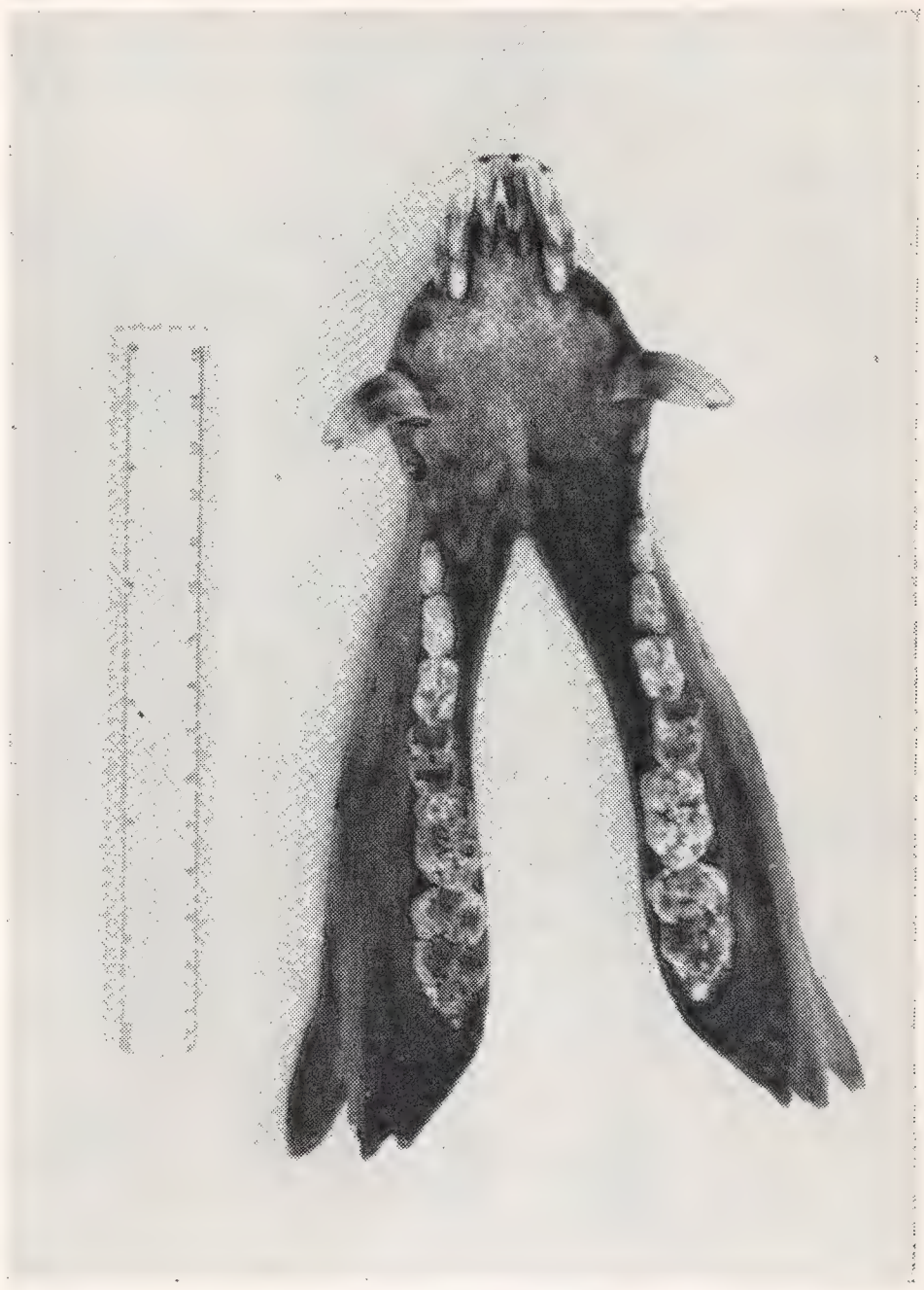

Figure 1. Lower jaw of pig *(Sus)* reported as peccary from the Pleistocene of Louisiana.

The lower jaw in question is that of a domestic pig (*Sus*) not a peccary (Figure 1). This element is uncataloged: however, the locality is written on the ramus, and the collector (Clair A. Brown) assured me of its authenticity.

Reported fossil material from this parish of Louisiana should be suspect as the gravels of the streams bear a mixture of fossil and modern forms. In the streams of this area I have found the slightly mineralized bones of modern horses, cows and pigs along with Pleistocene horses and probiscideans. I have collected a representative late Pleistocene vertebrate fauna (which will be reported in the near future) at a number of sites in West Feliciana Parish but have found no peccary remains. Although peccaries are known from the Pleistocene of Texas, Arkansas and Florida, and may well have occurred in Louisiana, no material to substantiate their presence has been reported to date.

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GEOLOGY OF THE LAVON AREA, COLLIN COUNTY, TEXAS

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CONTENTS

I. ABSTRACT 29
II. INTRODUCTION 30
III. STRATIGRAPHY 31
IV. STRUCTURE 36
V. SUMMARY OF CONCLUSIONS 38
VI. LITERATURE CITED 38
TABLE I: Distinctive Foraminiferida in the beds above and below the unconformity 33

ILLUSTRATIONS

PLATE I: Geologic map of the Lavon area ..... opposite page 30
PLATE II: Photomicrographs 35
PLATE III: Photomicrographs 37

I. ABSTRACT

The Lavon area, in southeastern Collin County, Texas, includes approximately 35 square miles. The rocks are of Cretaceous and Cenozoic age.

Cretaceous rocks are represented by the marine Taylor Formation, here divided on the basis of chemical and physical characteristics into four members: siltstone, lower marl, glauconitic limestone, and upper marl, named in ascending order.

The siltstone consists mostly of dark gray silt, and averages approximately 20 per cent solubles. The lower marl, the base of which is marked by a thin zone of irregular phosphatic nodules, is a pale brown, calcareous clay averaging about 55 per cent solubles. A disconformity separating the siltstone and lower marl is interpreted as a minor stratigraphic break of submarine origin. The glauconitic limestone is a very pale brown, sandy, and glauconitic fragmental rock that averages approximately 65 per cent solubles. The upper marl is similar in lithology to the lower marl but averages 47 per cent solubles. A hard, light gray layer of limestone occurs in the upper portion.

Tentatively, the siltstone is correlated with the Wolfe City member of the Taylor Marl. The overlying lower marl and glauconitic limestone members presumably are the equivalent of the Pecan Gap Chalk though radically different in lithology.

The Cenozoic strata are fluvial deposits in terraces and floodplains. The alluvium is composed mostly of clay and silt with subordinate amounts of pebble gravel.

In the Cretaceous sequence the attitude of bedding can be determined at only a few localities. The siltstone and glauconitic lime-

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stone members strike NNE, and even though slight steepenings occur locally, the average dip probably is less than one degree toward the east.

Joints are abundant in the Cretaceous rocks, especially in the lower marl. Several sandstone dikes, similar to those near Rockwall, Texas, cut the upper marl.

II. Introduction

The Lavon area, Collin County, Texas, (fig. 1) measures approximately 35 square miles. The area drains southward through the East Fork of the Trinity River, a sluggish perennial stream with intermittent tributaries. The total relief is 181 feet. Elevations range from 439 feet above sea level along the East Fork in the southern part of the area, to 620 feet in the upland north of the town of Nevada. Slopes rise gently from the floodplains to rolling uplands. The only steep slopes are along recent gullies.

Along East Fork and Pilot Grove Creek, levees have been constructed to prevent flooding of the bottom land. Construction of the Lavon Dam on the East Fork north of the St. Louis and Southwestern Railroad crossing was begun in 1948 and completed in 1953. The mapping of the Lavon area was completed in 1948 before the Lavon Reservoir filled up with water. The artificial lake has concealed part of the map area (pl. I). The dam controls floodwaters and provides water to surrounding towns, farms, and ranches.

There is no published account of detailed geological studies in the Lavon area, although there are several reports on the regional geology. Hill (1901) described the Cretaceous rocks in the Black and Grand Prairies of Texas, and Stephenson (1918) published an account of the stratigraphy of northeastern Texas. Stratigraphic reports by Dane and Stephenson (1928) and Stephenson (1929) include references to the Lavon area. Goldberg (1948) has mapped the area north of the Lavon area, and Clement (1950) the area to the southeast.

The Lavon area was mapped in detail (see pl. I). In the stratigraphic discussion emphasis is placed on the lithology of the Taylor beds. Mapping was done on aerial photographs with a scale of approximately 3 inches to 1 mile. A sketchmaster was used to transfer the contacts to an enlarged topographic base map adapted from the McKinney topographic sheet.

This study is part of a broader program of studies on the Upper Cretaceous stratigraphy and areal geology of northeastern

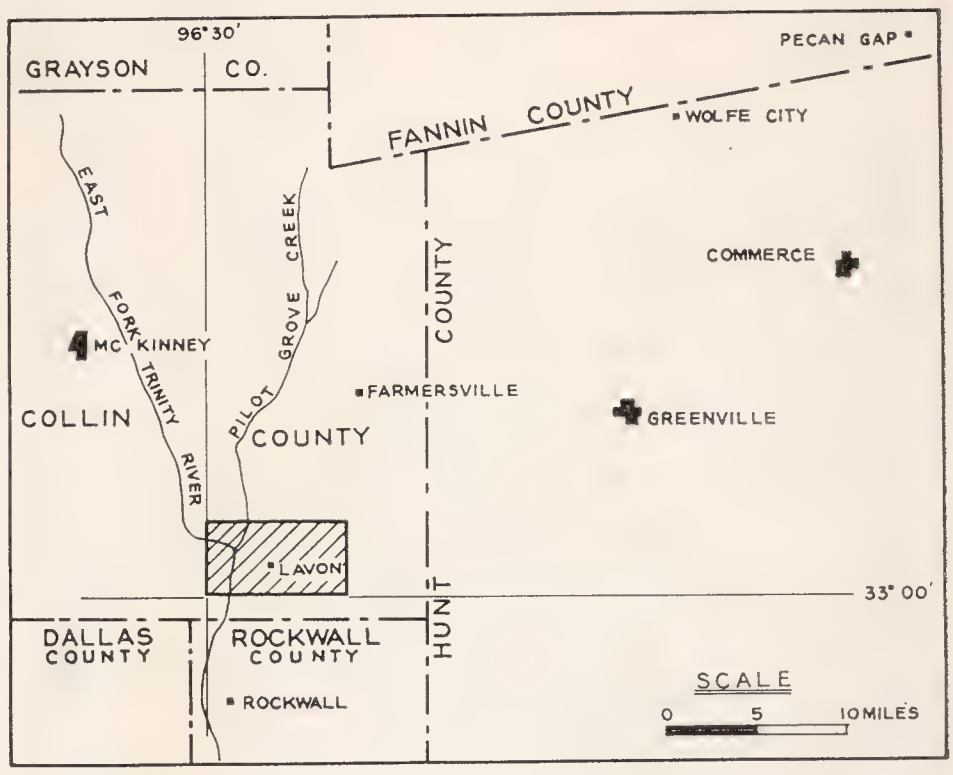


Figure 1. Map of a portion of northeastern Texas showing the location of the Lavon area (ruled section).

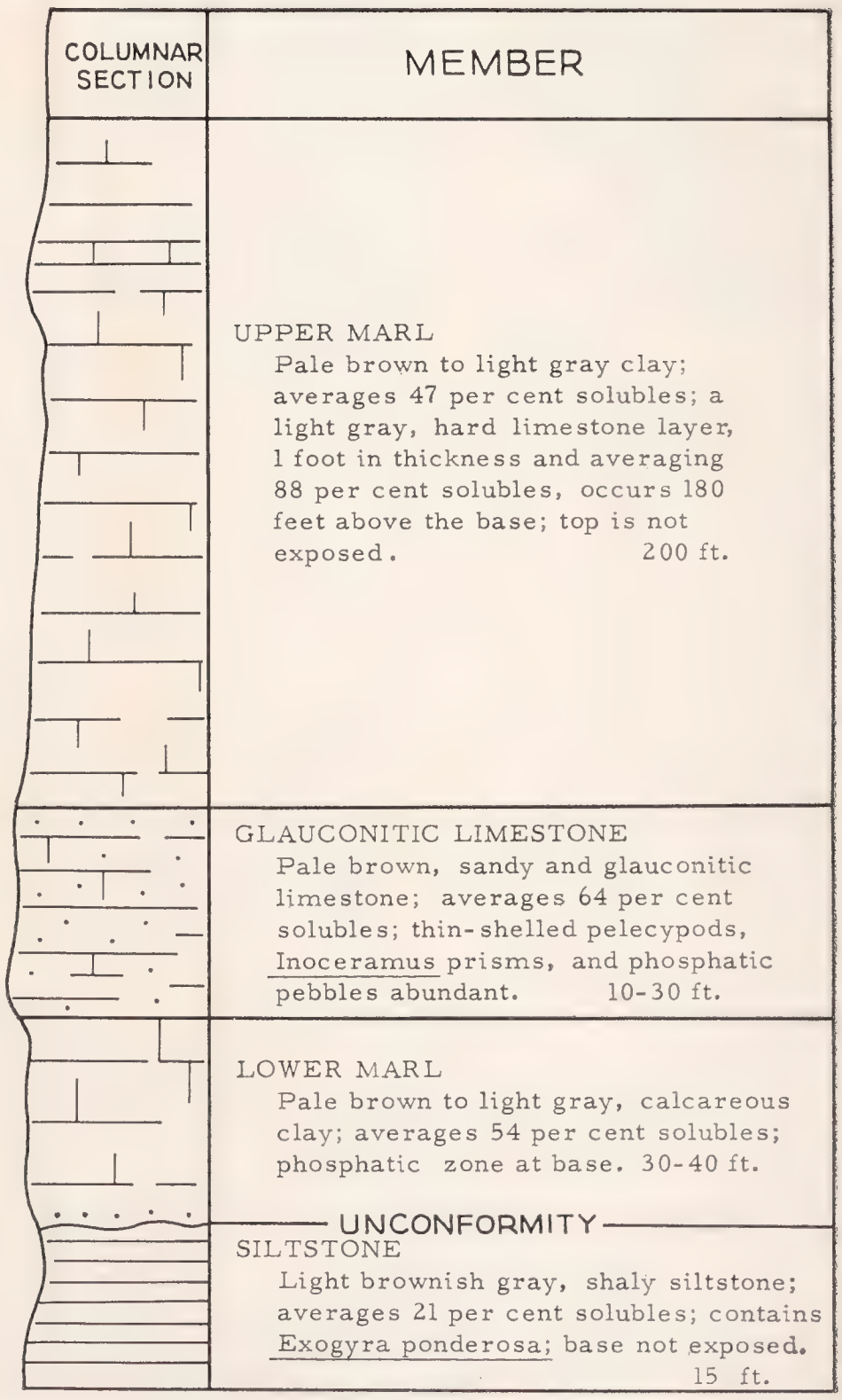


Figure 2. Generalized columnar section of the Taylor Formation in the Lavon area, Collin County, Texas.

N AREA

2 MILES

UADRANGLE

ITS LIMESTONE LAYER)

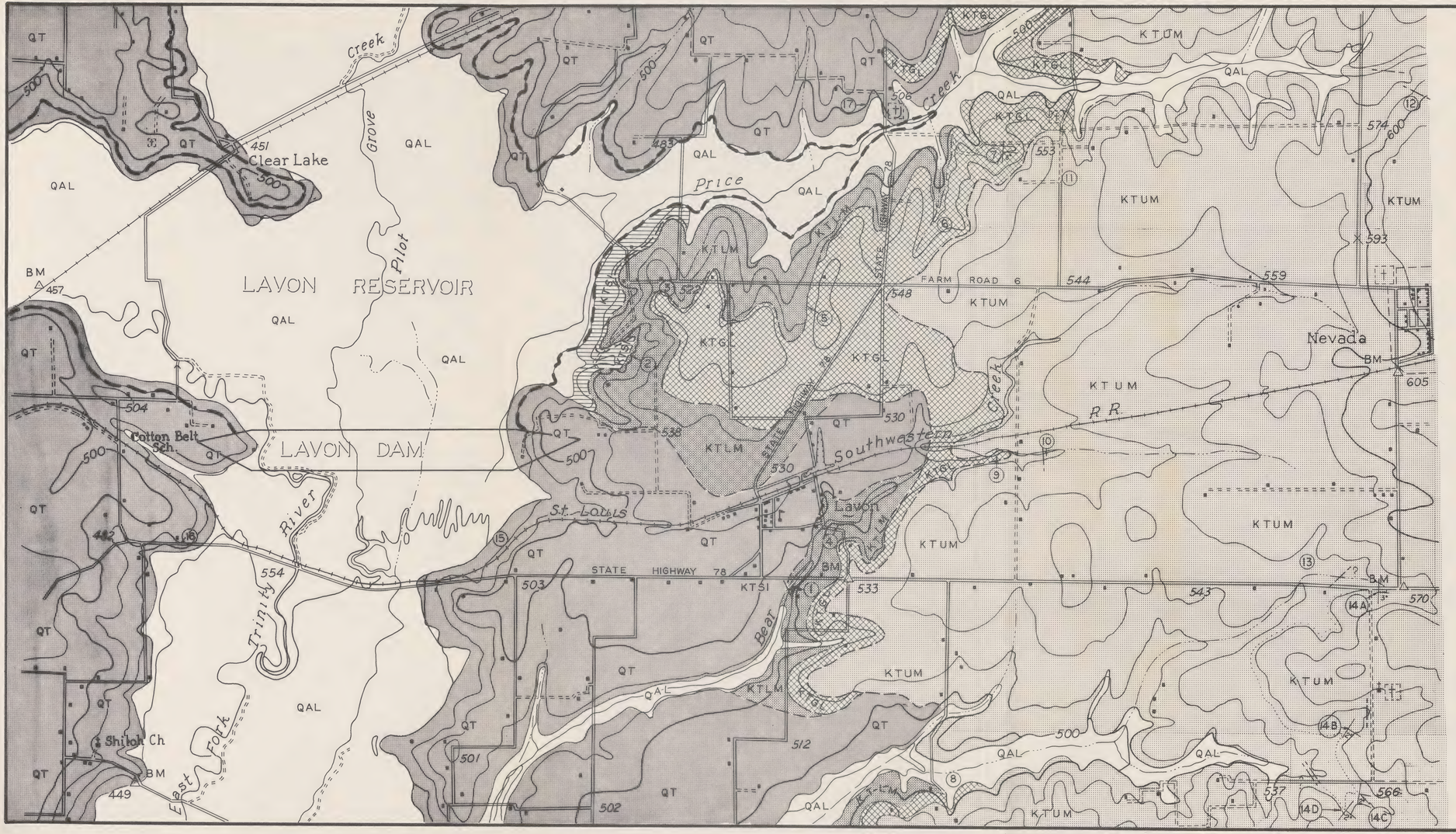
ONE

OS

REFERRED TO IN TEXT

AREA OUTLINE

PLATE I



GEOLOGIC MAP OF THE LAVON AREA
COLLIN COUNTY, TEXAS

BY

R.O. STEINHOFF

0 1 2 MILES

CONTOUR INTERVAL = 20'

BASE ADAPTED FROM U. S. G. S. MC KINNEY QUADRANGLE

LEGEND

CENOZOIC ROCKS

- QAL — ALLUVIUM
- QT — TERRACE

CRETACEOUS ROCKS

TAYLOR FORMATION

- KTUM — UPPER MARL (DOTTED LINE REPRESENTS LIMESTONE LAYER)
- KTGL — GLAUCONITIC LIMESTONE
- KTLM — LOWER MARL
- KTSI — SILTSTONE

- SANDSTONE DIKE
- 2° — STRIKE & DIP OF BEDS
- (1) — LOCALITY NUMBERS REFERRED TO IN TEXT
- LAVON RESERVOIR AREA OUTLINE

T.N. 9°

PLATE I

Texas sponsored by the Department of Geology at Southern Methodist University. Sincere thanks are due Dr. C. C. Albritton, Jr. for his continued interest and criticism during the course of this work. The author is grateful to Dr. Arthur Richards and Dr. Ellis W. Shuler for valuable advice. Mrs. Kathleen Keathley identified the microfossils and Mr. William Webber photographed the thin-sections and phosphatic nodules. Mr. Stanley Hardison assisted in the field. The writer is indebted to the editorial committee: Dr. C. C. Albritton, Jr., Dr. C. L. McNulty, Jr., and Dr. William L. Russell for their advice and criticism.

III. Stratigraphy

Upper Cretaceous Rocks

Taylor Formation

The Cretaceous rocks in the Lavon area are part of a sequence, first known as the "Blue Bluffs division" or "*Exogyra ponderosa* marls," and later named "Taylor marl" by Hill (1892, p. 73). It lies between the Austin and Navarro formations and is estimated (Stephenson, 1918, p. 154) to be 500 to 600 feet thick in northeastern Texas. Stephenson *(loc. cit.)* states that the Taylor of northeast Texas is chronologically equivalent to only the upper part of the formation at its type locality in Williamson and Travis counties.

In the Lavon area the Taylor is mostly concealed by alluvium or soil. The best exposures are in gullies and artificial excavations, and the more enlightening of these localities have been numbered on Plate I.

On the basis of chemical and physical characteristics, that portion of the formation which crops out in the Lavon area is divided into four members: siltstone, lower marl, glauconitic limestone, and upper marl (see fig. 2).

Siltstone—The siltstone member, which contains particles ranging in size from fine sand to clay with silt predominant, is when wet, dark gray and plastic, and when dry, light brownish gray. This member is somewhat sandy, and commonly shows shaly parting. In places it is fossiliferous, containing *Exogyra ponderosa* Roemer, poorly preserved baculitids, small pelecypods, and gastropods. The soluble content of eighteen samples tested ranged from 11 to 31 per cent and averaged 21 per cent.

The member crops out at only two places within the area. At locality 1, there are exposed ten to fifteen feet of light brownish gray, indistinctly bedded siltstone, containing scattered *Exogyra ponderosa.* Three feet of dark gray siltstone are present at locality 2, with *Exogyra ponderosa* scattered on the surface. The maximum thickness of 15 feet was measured along Bear Creek at locality 1. The base of the siltstone is not exposed in the Lavon area.

Two thin-sections from locality 1 showed scattered, irregular grains of quartz and calcite embedded in an extremely fine-grained, light brownish gray, granular matrix (pl. II, fig. 1). There are several microfossils, including *Heterohelix* and *Globigerina.* Minute grains of an opaque substance present could not be identified.

Lower marl member—The lower marl member is a calcareous clay, medium olive gray on moist fresh exposures but drying pale brown to light gray. It weathers to plastic clay. The thirty samples tested varied from 48 to 66 per cent solubles and averaged 54 per cent. This represents an average of 17 per cent increase in solubles over the siltstone member.

At the base of the member is a two-inch zone of irregularly shaped brown to black phosphatic nodules. These range from a fraction of an inch to 4 inches across, and are oriented with the longest dimensions parallel to the bedding. Associated with the irregular nodules are phosphatized shark teeth and phosphatic casts of gastropods, ammonites, and pelecypods. Many of the nodules contain irregular openings evidently formed by boring organisms. Bryozoans and pelecypods, attached to some of the nodules, show no signs of wear.

The phosphatic zone is clearly exposed at the base of about 10 feet of a light gray marl at localities 1 and 2. Exposures of the overlying marl may be seen in gullies trending eastward at locality 3, where 3 to 5 feet of a very pale brown marl crop out. At locality 4 there are exposed approximately 15 feet of a light gray marl with indistinct bedding. The total thickness of the member is estimated at between 30 and 40 feet.

A thin-section of the lower marl from locality 1 shows foraminiferal tests and scattered, irregular grains of quartz and calcite set in an extremely fine-grained, light gray granular matrix (pl. II, fig. 2).

Two thin-sections of a phosphatic nodule collected from locality 1 reveal that approximately two-thirds of the nodule consists of scattered, extremely irregular quartz grains. The remaining third is composed of a matrix of black, opaque, phosphatic material of unknown composition. Scattered irregular grains of glauconite and calcite and calcite fillings are present (pl. II, fig. 3).

A thin-section of a phosphatic gastropod cast shows abundant, irregular quartz grains embedded in a light brown, fine-grained phosphatic matrix of unknown composition. *Inoceramus* prisms and grains of calcite and glauconite are also present. Scattered minute grains of an opaque substance could not be identified (pl. II, fig. 4).

Relation of the siltstone and lower marl members—At localities 1 (fig. 3a) and 2 the lower marl rests unevenly upon the siltstone with angular discordance of 4 to 5 degrees. The light gray marl fills channels and cracks cut in the underlying light brownish gray siltstone, and irregular fragments of siltstone are set in the light gray marl (fig. 4). The origin of the extremely irregular surface is not known. However, the contact between the two members is clearly one of erosion and indicates a disconformity. Furthermore, the distribution of microfossils at this locality indicate a "faunal break" at the contact (see table I).

Phosphatic nodules, as already described, occur along and immediately above the erosional contact. Such nodules may form where a sea bottom has attained the base level of deposition (Twenhofel, 1939, p. 475). Teal (1900, p. 382) states that:

> " . . . phosphatic nodules represent long periods of time," and that "they occur in areas of minimum sedimentation, or where the sediment once formed has been subsequently removed by submarine erosion, probably not long after its accumulation."

Both the siltstone and lower marl members were formed under marine conditions as the abundant Foraminiferida attest. However, the erosional contact and the concentration of phosphatic nodules along that surface could indicate either subaerial or submarine conditions during the hiatus.

Stephenson (1929, p. 1331) refers to the "unmistakeable unconformity" one half mile south of Lavon (loc. 1). According to Stephenson, an "unconformity" indicates the following succession of events: (1) uplift of a sea bottom, (2) subaerial erosion of that surface, (3) the sinking of that area, and (4) the continuation of sedimentation.

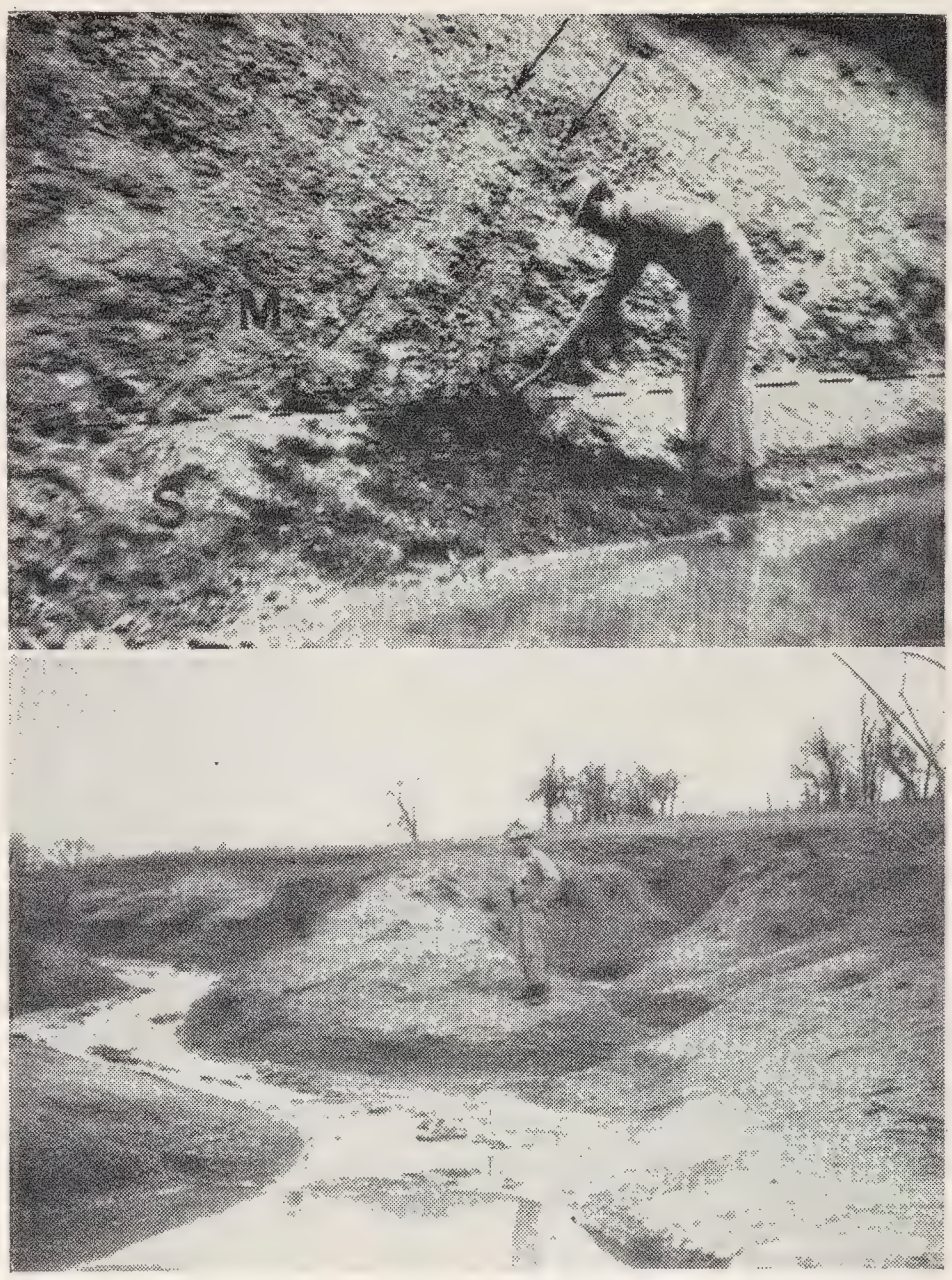


Figure 3.
a. Contact between the siltstone and lower marl members at locality 1. Arrows denote joints.
b. Glauconite limestone member 2 miles northeast of Lavon.

Twenhofel (1936, p. 696) states that:

> " . . . phosphatic nodules may be allothogenic in the sense that they were released on subaerial weathering from strata in which they were more or less widely scattered, and if such is the case they can have no bearing on the occurrence of a submarine unconformity. On the other hand they may be pene-authigenic in that they developed in the sediments of the bottom and when subsequent conditions lowered the base level of deposition the finer materials were removed and the nodules concentrated. Again, they may be of strictly authigenic deposition with other sediments developed in association moved concomitantly on formation leaving the nodules. A submarine discontinuity exists in the last two cases."

Specific evidence for subaerial conditions, such as terrestrial deposits or soil profiles, is lacking. Delicate features of the phosphatic nodules as well as fossil shells adhering to them would likely be worn or removed

under subaerial conditions. They do not show much wear. In fact, there is no reason for supposing that subaerial conditions existed here in lower Taylor time. The microfauna and phosphatic nodules both indicate a marine environment. The irregular surface of unconformity could have been produced by the combined activities of boring organisms and submarine currents working on bottoms built to the profile of equilibrium. During the interval when sedimentation was at a stand-still, the phosphatic nodules grew. When sediments again accumulated, these were incorporated in the base of the lower marl member.

Glauconitic limestone member.—This is an indistinctly bedded sandy limestone containing up to 15 per cent glauconite. It is very pale brown on fresh exposures but weathers yellowish. Ten samples tested indicated 58 to 74 per cent soluble matter and averaged 64 per cent. The insoluble fraction is largely of sand-size glauconite and quartz grains with a few grains of brown resinous material of unknown composition. Texturally, this member is a sandstone.

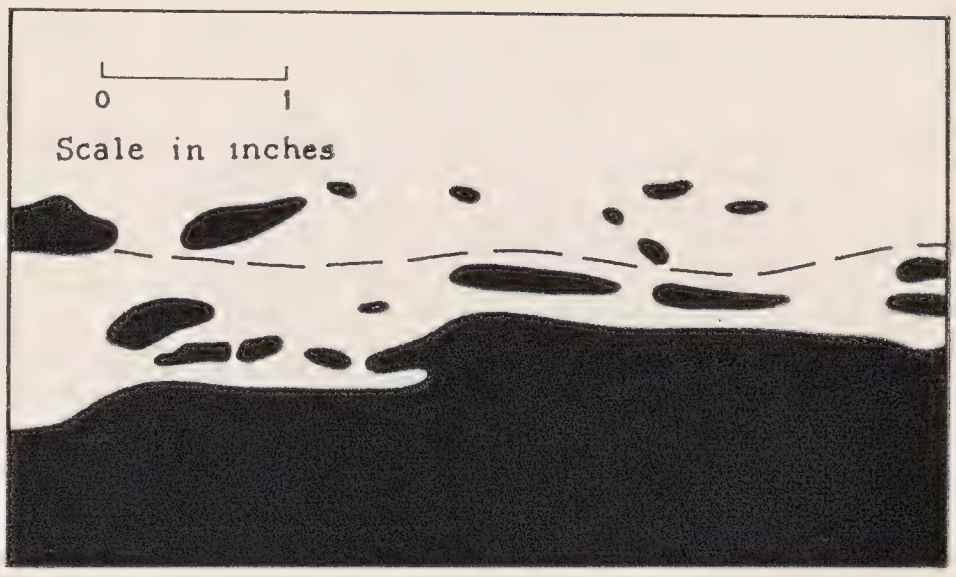


Figure 4. Drawing of the uneven surface between the siltstone (shaded area) and the overlying lower marl members at locality 1. Dashed line represents a weak yellow shaly parting.

Plano-convex objects with chevron markings on the convex side are scattered over the surface near the base of this member. They are weak yellow, vary in length from 1 to 4 inches, and are composed of resistant sandy limestone. Their origin is unknown.

At localities 7 (fig. 3b) and 9, ten to fifteen feet of yellowish gray glauconitic limestone is exposed. Phosphatic pebbles and pebble casts, *Inoceramus* prisms, and specimens of a thin-shelled pelecypod readily weather from the upper portion of these sections. At localities, 5, 6, and 8, one to four feet of yellowish gray, glauconitic limestone, containing scattered phosphatic pebbles, overlie two to three feet of the lower marl member. The very pale brown marl contains poorly preserved baculitids, pelecypods, and gastropods.

The maximum exposed thickness of 15 feet is visible at localities 7 and 9. The total thickness of the glauconitic limestone member in the Lavon area is estimated at 30 feet.

Thin-sections from localities 7, 8 and 9 show abundant irregular grains of quartz and glauconite set in a matrix of calcite. *Inoceramus* prisms, foraminifers, and minute grains of zircon are noted (pl. III, fig. 1). *Globigerina* and *Heterohelix* are the most abundant Foraminiferida present. *Nodosaria* and *Planulina* occur but are rare.

Microscopic examination of a sandstone object showing chevron markings, collected north of locality 5, shows a matrix of calcite

TABLE I

DISTINCTIVE FORAMINIFERIDA IN THE BEDS ABOVE AND BELOW THE UNCONFORMITY

LOWER MARL	
Bolivinoides decorata (Jones)	A
Bolivinopsis rosula (Ehrenberg)	R
Bulimina reussi Morrow	C
Chrysalogonium eximium Cushman	N
Dentalina alternata (Jones)	R
Dentalina fragments	C
Dentalina gracilis d'Orbigny	R
Gaudryina ellisorae Cushman	R
Globorotalia? multiloculata Morrow	R
Globorotalites micheliniana (d'Orbigny)	N
Heterostomella austinana Cushman	R
Lagena sulcata (Walker and Jacob)	R
Loxostomum sp.	C
Nodosaria sp.	R
Stilostomella stephensoni (Cushman)	A
UNCONFORMITY	
SILTSTONE	
Frondicularia sp.	R
Heterohelix carinata (Cushman)	R
Heterohelix globocarinata (Cushman)	N
Marginulina texasensis Cushman	R
Pseudoclavulina sp.	A
Textularia sp.	R

EXPLANATION:

R = Rare, 1-3 C = Common, 8-15
N = Numerous, 3-8 A = Abundant, 15+

Figure 5. Meander scar in upper marl member in tributary of Bear Creek south of the St. Louis Southwestern railroad.

enclosing larger, abundant, irregular grains of quartz. Scattered grains of glauconite and *Inoceramus* prisms are noted (pl. III, fig. 2). Microfossils present include *Globigerina, Nodosaria, Heterohelix, Planulina,* and ostracods.

Upper marl member.—The upper marl member is lithologically similar to the lower marl member. Thirty samples tested varied from 38 to 56 per cent solubles with a progressive increase toward the southeast. The average solubility is 47 per cent.

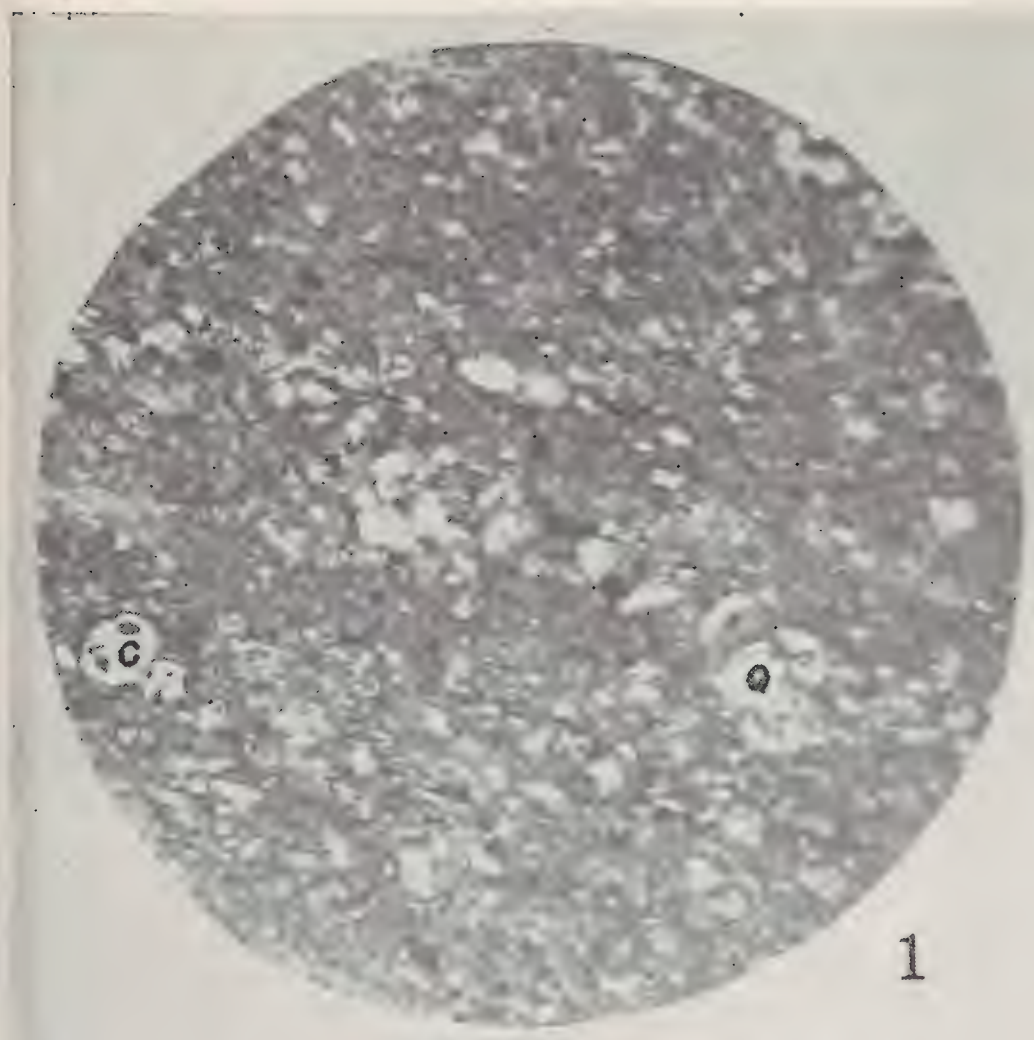
At locality 10 (fig. 5), approximately ten feet of very pale brown marl crops out. Other outcrops from 2 to 5 feet thick are exposed in gullies at localities 11, 12, and 13.

The greatest observed thickness of 10 feet is exposed at locality 10. The top of the member is not exposed in the Lavon area. The estimated thickness of the upper marl member is two hundred feet.

A thin-section from locality 10 shows scattered irregular and rounded calcite grains embedded in an extremely fine-grained, light brownish gray, granular matrix (pl. III, fig. 3). Several *Planulina, Heterohelix, Globigerina,* and minute grains of quartz are present. Marcasite occurs in small spheroidal and botryoidal masses.

Toward the southeastern corner of the area, a light gray, hard, massive, limestone layer 10 to 13 inches thick is present in the upper marl. The layer contains scattered large pelecypods, smaller gastropods, and baculitids. The solubility of the limestone layer ranges from 86 to 91 per cent, while the marl above and below varies from 45 to 60 per cent. This layer is typically developed near the junction of two small creeks at localities 14C and 14D. Other exposures may be examined 1.5 miles to the north of these outcrops (locs. 14A & 14B). Nowhere in the Lavon area was the upper marl seen in contact with the underlying glauconitic limestone member.

A thin-section from locality 14B shows that nearly two-thirds of the limestone layer is composed of clay. The remaining third consists of almost perfectly spherical bodies. These peculiar grains are surrounded by a wall of finely granular, crystalline calcite. The center of the cells, though often hollow, commonly is filled with minute calcitic crystals (pl. III, fig. 4). Mrs. Keathley (per-



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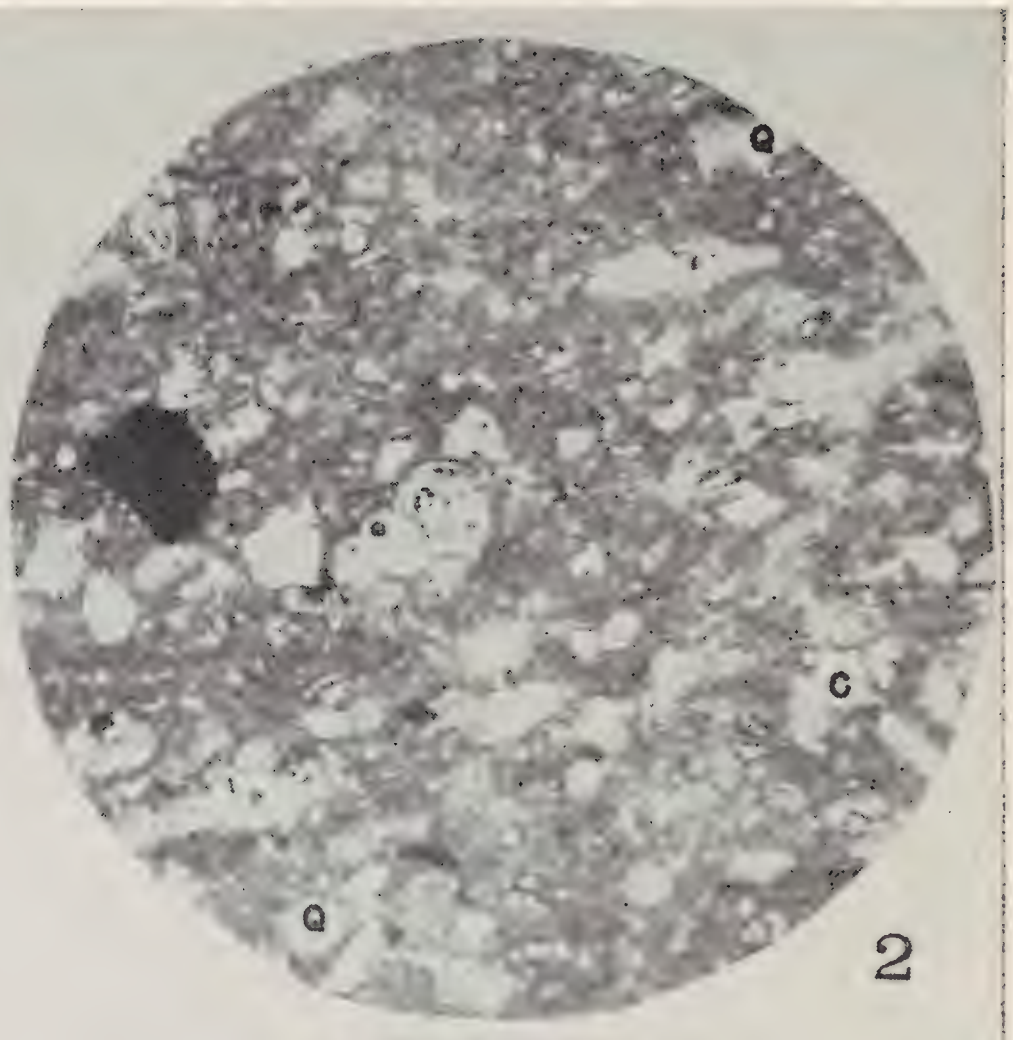

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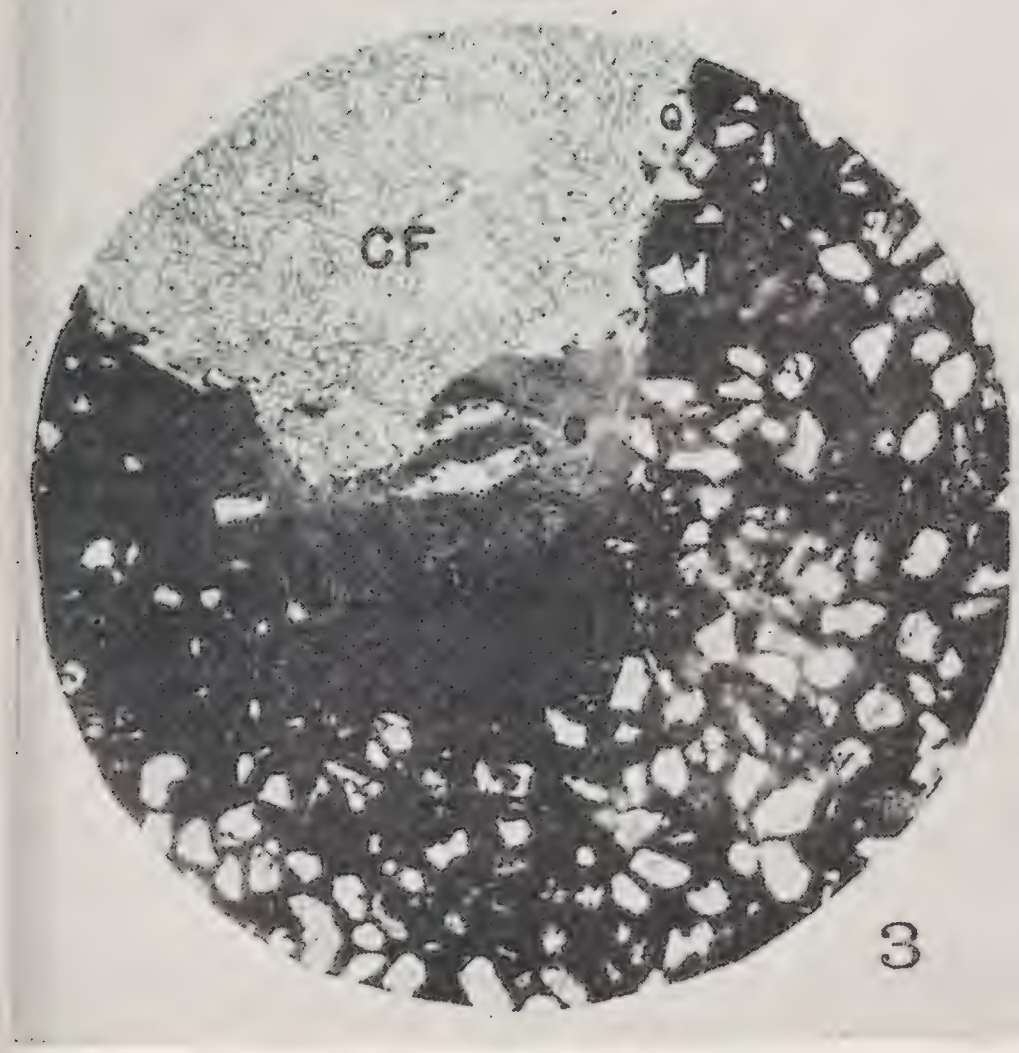

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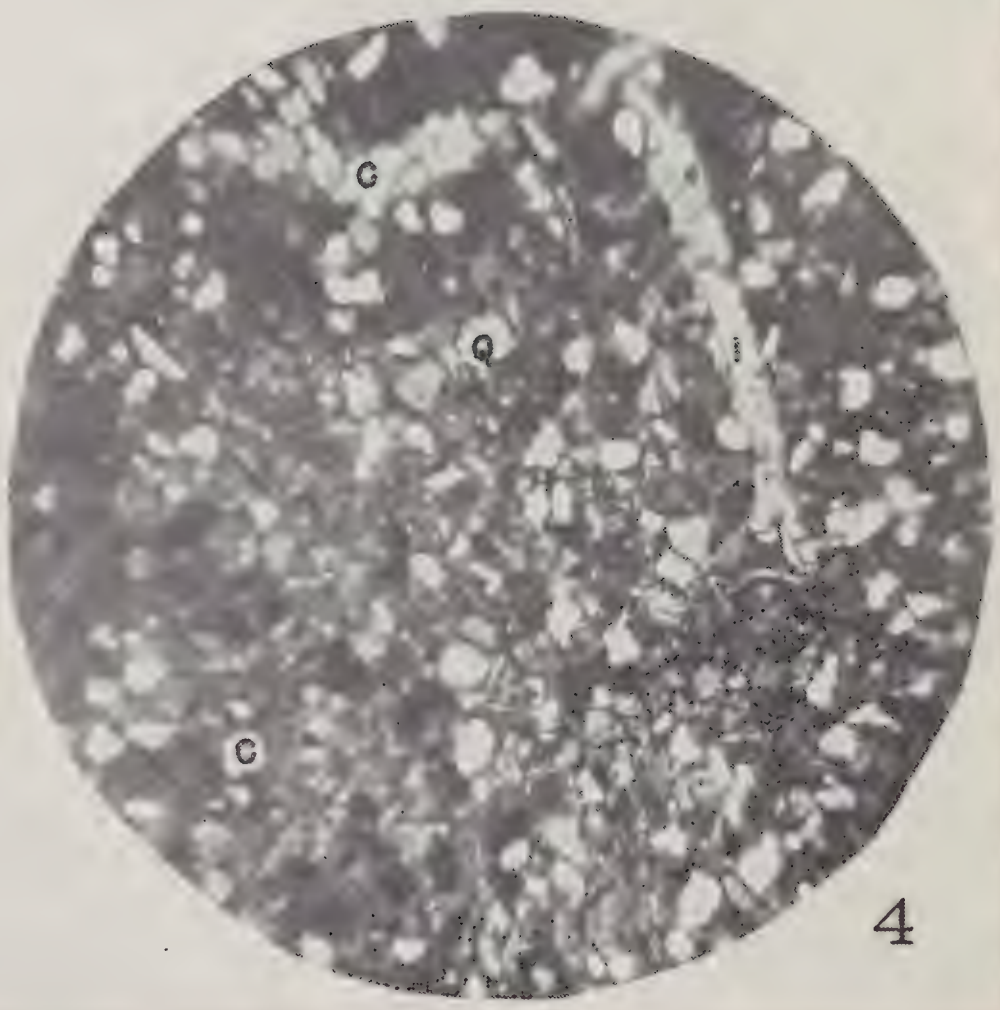

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Plate II. Photomicrographs

1. Siltstone from locality 1. The clear material, quartz (Q) and calcite (C), is embedded in a dark granular matrix. Ordinary light, X 75.

2. Lower marl from locality 1. The clear material, embedded in a dark-colored matrix, is quartz (Q) and calcite (C). Ordinary light, X 52.

3. Phosphatic nodule from locality 1. The clear, irregular grains, embedded in the black phosphatic matrix, are quartz (Q). Calciite grains (C) are present, and the upper portion, labeled CF, is a calcite filling. Note the patch of glauconite (G) in the end of the filling. Ordinary light, X 30.

4. Phosphatic gastropod cast from locality 1. The clear material, quartz (Q) and calcite (C), is embedded in a dark-colored matrix of phosphatic material. Note the *Inoceramus* prism of calcite (I) in the upper right portion. Polarized light, X 45.

sonal communication) states that these bodies are not Foraminiferida. Tarr (1925, p. 263) identified similar bodies in the English Chalk as chemically formed oölites.

Correlation.—On the State Geologic Map (Darton, *et al.,* 1937) the Taylor Formation in the Lavon area is divided into the lower marl, the Wolfe City Sand, the Pecan Gap Chalk, and the upper marl. The Wolfe City and Pecan Gap members were named by Stephenson (1918, p 154-156) for localities in Hunt and Fannin Counties. Stephenson *(loc. cit.)* states that at its type locality the Wolfe City is a fine calcareous gray sand or sandy marl containing *Exogyra ponderosa* Roemer. The Pecan Gap at its type locality consists of bluish gray, slightly bituminous, more or less argillaceous and sandy chalk, weathering to light gray and white.

Dane and Stephenson (1928, p. 42-43) state that at the type locality of the Pecan Gap Chalk

> " . . . the basal chalk is glauconitic, contains numerous phosphatic nodules, and rests upon the somewhat irregular surface of the top of the Wolfe City Sand. The Wolfe City elsewhere contains irregular beds and lenses of some of these, well within the base of the Pecan Gap."

They further state that, at a point 1.2 miles north of Lavon, the basal Wolfe City is a glauconitic marly sand containing casts of fossils and irregular phosphatic nodules. The "glauconitic marly sand" is undoubtedly the glauconitic limestone of this report. Thus, according to their interpretation, the glauconitic limestone is Wolfe City and the underlying siltstone and lower marl members belong in the "lower marl" as shown on the state map. However, Rouse (1944, p. 525-526) places the contact between the Wolfe City and Pecan Gap in the Farmersville area (fig. 1) along a phosphatic zone at the base of a series of glauconitic limestone beds which are lithologically identical with the glauconitic limestone of this report. By this correlation the glauconitic limestone is Pecan Gap.

In the writer's opinion the only stratigraphic break, that at the base of the lower marl member, is the logical horizon for separating the Wolfe City equivalent from the Pecan Gap equivalent. Tentatively the siltstone is correlated with the Wolfe City Sand. The siltstone member is somewhat sandy, contains *Exogyra ponderosa* Roemer and therefore is similar in important respects to the Wolfe City at its type locality. It would follow that the lower marl and glauconitic limestone members are Pecan Gap time equivalents.

Quaternary Beds

The Quaternary of the Lavon area consists predominantly of terrace and floodplain deposits of the East Fork of the Trinity River and its tributaries. Deposition continues along the present floodplains.

Terrace Deposits—Terrace deposits are present on both sides of the floodplains of the East Fork and Pilot Grove Creek. The particles of the deposits range from pebble size down to clay. There are three good exposures in the Lavon area. At locality 15, a two inch basal pebble conglomerate is overlain by 9 feet of pale yellow sands containing thin pebble lenses. Small patches of a pebble conglomerate may be seen in abandoned gravel pits at localities 16 and 17. Most pebbles are pink to white quartzite of unknown provenance. They could not have been derived from any of the formations over which the East Fork flows. Their immediate origin may well have been terrace deposits stripped from the higher areas.

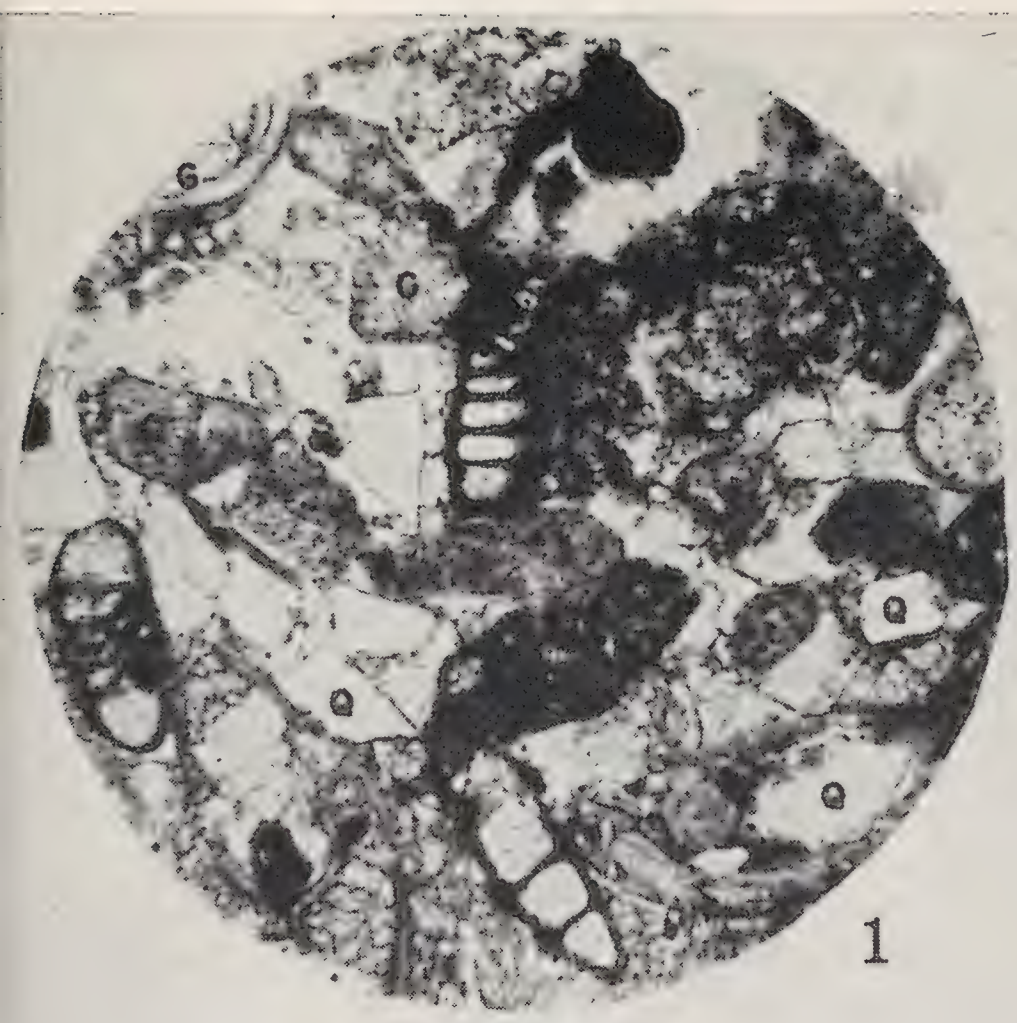
Floodplain Deposits—The floodplains of the East Fork of the Trinity River and Pilot Grove Creek have average widths of about one mile. The alluvium includes clay, silt, sand, and gravels, essentially the same materials found in the terraces.

Clay galls, along creek bottoms in the eastern part of the Lavon area, consist of fragments of Taylor Marl that have been rolled along the bottoms of gullies, gathering pebbles and sticky marl fragments and building more or less spherical balls up to 8 inches in diameter. Most of them crumble when collected.

IV. Structure

Strike and Dip

At only a few outcrops could the attitude of the beds be determined, as exposures are generally small and dips so gentle that the beds appear to be essentially horizontal. At locality 1 the siltstone strikes N 28° W and dips 3° NE. The glauconitic limestone at locality 7 strikes NNE and dips 2 to 3°. The overall strike appears to be NNE but the average dip could not be determined.



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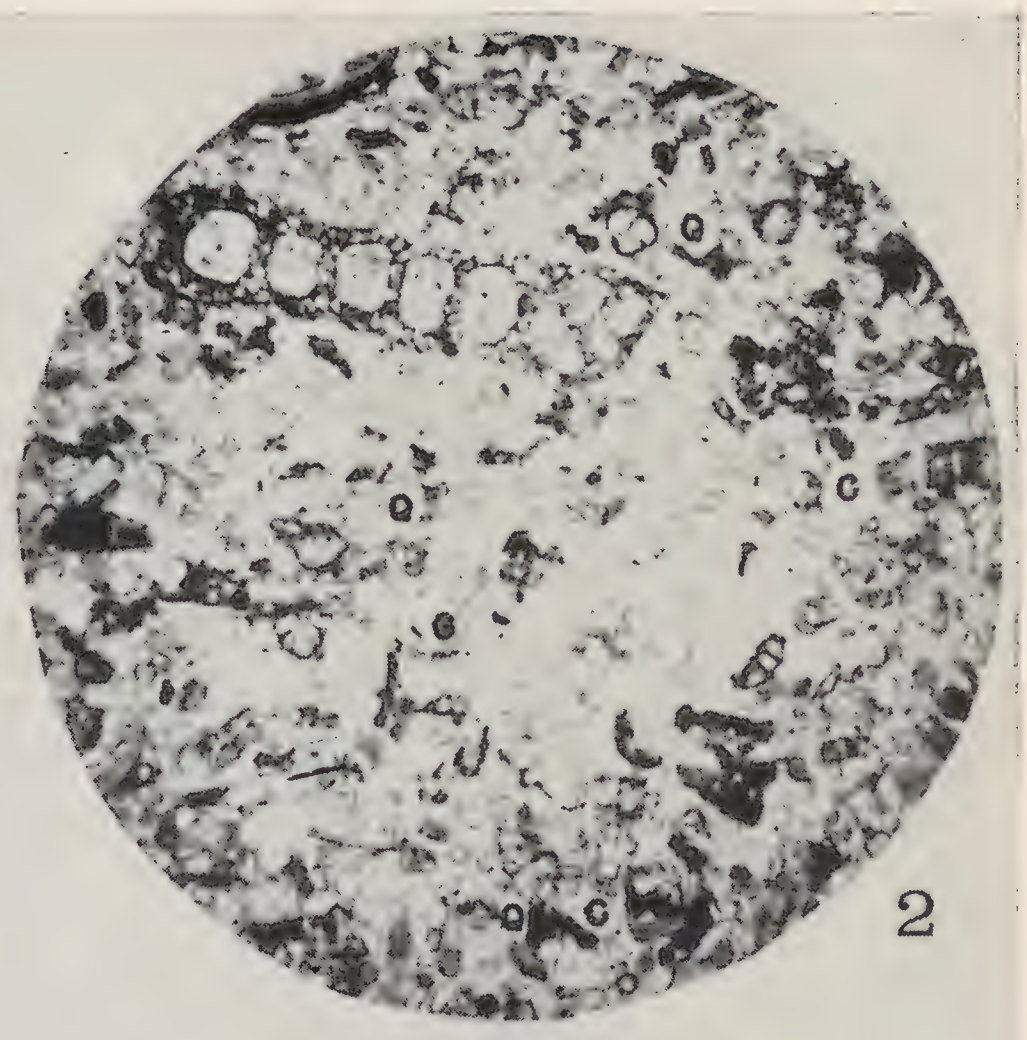

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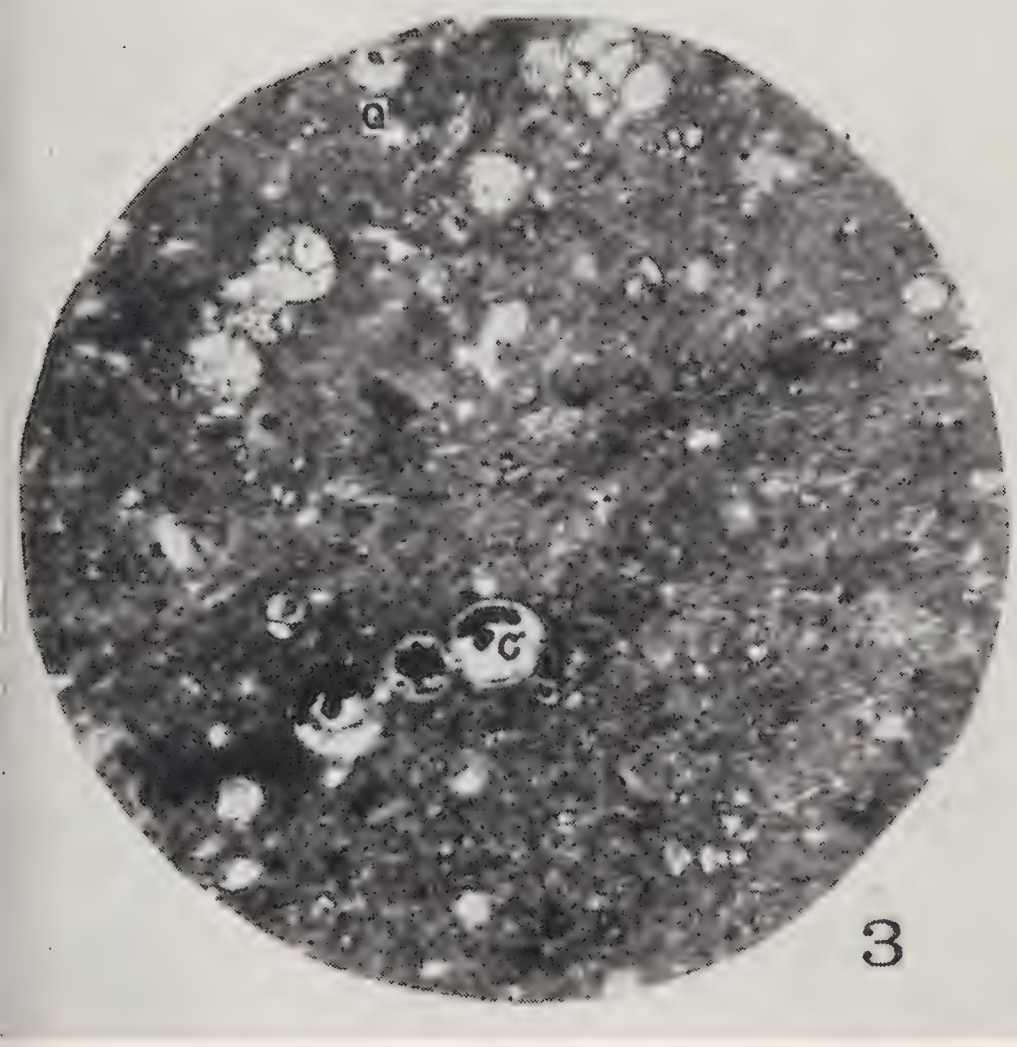

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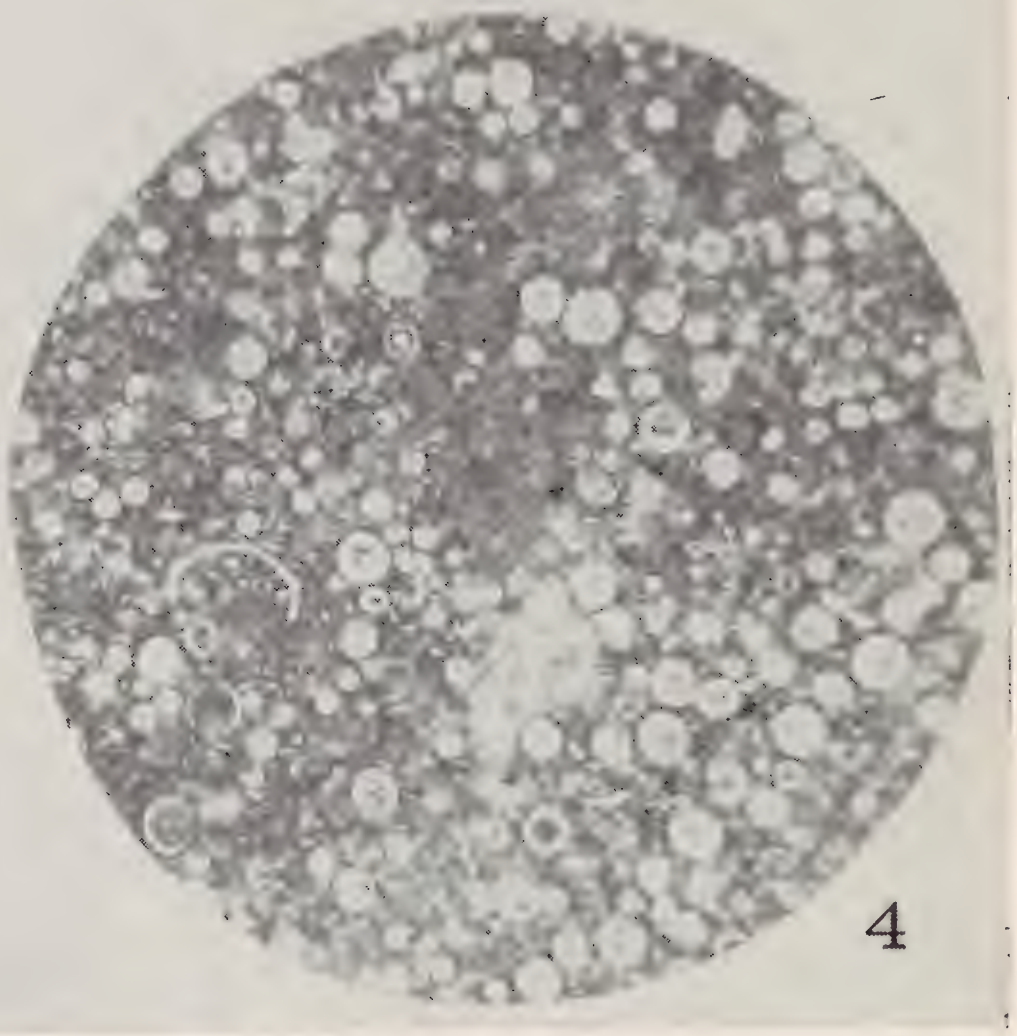

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Plate III. Photomicrographs

1. Glauconitic limestone from locality 7. The clear material is quartz (Q), and the gray material mainly the matrix of calcite. The darker grains are glauconite (G), while the 6 sided grains are of calcite (C). Note the microfossils in the lower and central portions. The rounded shape in the extreme right portion is a calcite-filled microfossil. Ordinary light, X 60.
2. Sandstone showing chevron markings from north of locality 5. The matrix of calcite encloses the abundant clear grains of quartz (Q) and dark grains of glauconite (G). Note the large microfossil in the upper portion. Ordinary light, X 26.
3. Upper marl from locality 10. The rounded, clear material, calcite (C), and the smaller, irregular grains of quartz (Q) are enclosed by a dark, finely granular matrix. The small, rounded, black opaque material within the larger calcite grains in the lower left portion is marcasite. Ordinary light X 75.
4. Limestone layer from locality 14B. The clear rounded spherical bodies of calcite are embedded in a dark-colored matrix. Ordinary light, X 45.

Joints

Joints are numerous in the Cretaceous rocks of the Lavon area and may be observed at nearly every locality cited in this report. However, they are more common in the lower and upper marl members. Locally, in these members the marl tends to fracture into long rectangular blocks 1 to 3 inches thick on both sides of the joint plane. Many of the joint planes are iron stained and filled with clay and sand particles.

Sandstone Dikes

Several sandstone dikes penetrate the upper marl member. Outcrops are limited to meander scars and deep gullies, but many dike fragments are scattered over the creek and gully bottoms in the eastern part of the area. The dikes vary in thickness from a fraction of an inch to 3 to 4 inches, commonly occurring in pairs, separated by a few feet of marl.

A vertical sandstone dike, striking N 40° E, at locality 10 cuts through the outcrop of marl and can be traced several yards to the south. The marl appears to have slumped downward and toward the dike for approximately 2 feet on both sides.

V. Summary of Conclusions

1. The Taylor Formation in the Lavon area may be divided into four members: siltstone, lower marl, glauconitic limestone, and upper marl.

2. A disconformity exists between the siltstone and lower marl. This does not necessarily signify uplift and subaerial erosion of the siltstone as Stephenson has assumed. It is simpler to suppose the break marks a bottom that was scoured by submarine currents during a pause in sedimentation. This lapse of time permitted the growth of accumulation of phosphatic nodules, which were later incorporated in the base of the lower marl.

3. The siltstone is tentatively correlated with the Wolfe City Sand and the lower marl and glauconitic limestone members with the Pecan Gap Chalk. However, the Pecan Gap Chalk at its type locality differs in lithology from any of the members given in this report, and it would be confusing to use the name for any of the rocks in this area.

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THE GENUS *TURBINELLA* (Mollusca, Gastropoda) IN THE NEW WORLD

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CONTENTS

I. ABSTRACT 39
II. INTRODUCTION 39
III. ACKNOWLEDGMENTS 42
IV. SYSTEMATIC DESCRIPTIONS 43
V. LOCALITY DATA 64
VI. LITERATURE CITED 65
VII. APPENDIX I: Nomenclatorial note on the name *Turbinella* Lamarck 66
TABLE I: Geologic and geographic distribution of New World species of *Turbinella* 40

ILLUSTRATIONS

TEXT FIGURE 1 48
PLATE I 45
PLATE II 57
PLATE III 63

I. ABSTRACT

Two lines of *Turbinella* have developed from the ancestral Eocene species, one in the Old World and one in the New World. The evolutionary development of these has been remarkably parallel, although apparently separate. In both regions the earliest species are shouldered forms, and successive species become increasingly smooth. In the New World a secondary group developed in the lower Miocene. This branch, here called the *"angulata"* lineage, is marked by an exceedingly large nucleus, and by a noded shoulder in contrast to the smooth outline of the primary form, here termed the *"laevigata"* lineage.

In this paper the 24 known species of New World Turbinellinae are treated systematically, and one new species, *Turbinella dalli,* is described. In addition the homonym *T. praeovoidea* Maury, *non* Vredenburg, is replaced by *T. praelaevigata, nom. nov.*

II. INTRODUCTION

The oldest known species of *Turbinella* Lamarck, 1799, (type species: *Voluta pyrum* Linnaeus) appears in the uppermost lower Eocene of Peru. From this "ancestral" species, *Turbinella peruviana* (Olsson), if it is truly such, there arose a New World line and an Old World line. The earliest species known from the Old World, *Turbinella episoma* (Michelotti), occurs in the Oligocene of the Mediterranean and India. This species is the only European *Turbinella,* all of the younger Old World forms presently known are from India and adjacent areas. Vredenburg (1923, p. 120) suggested that "com-

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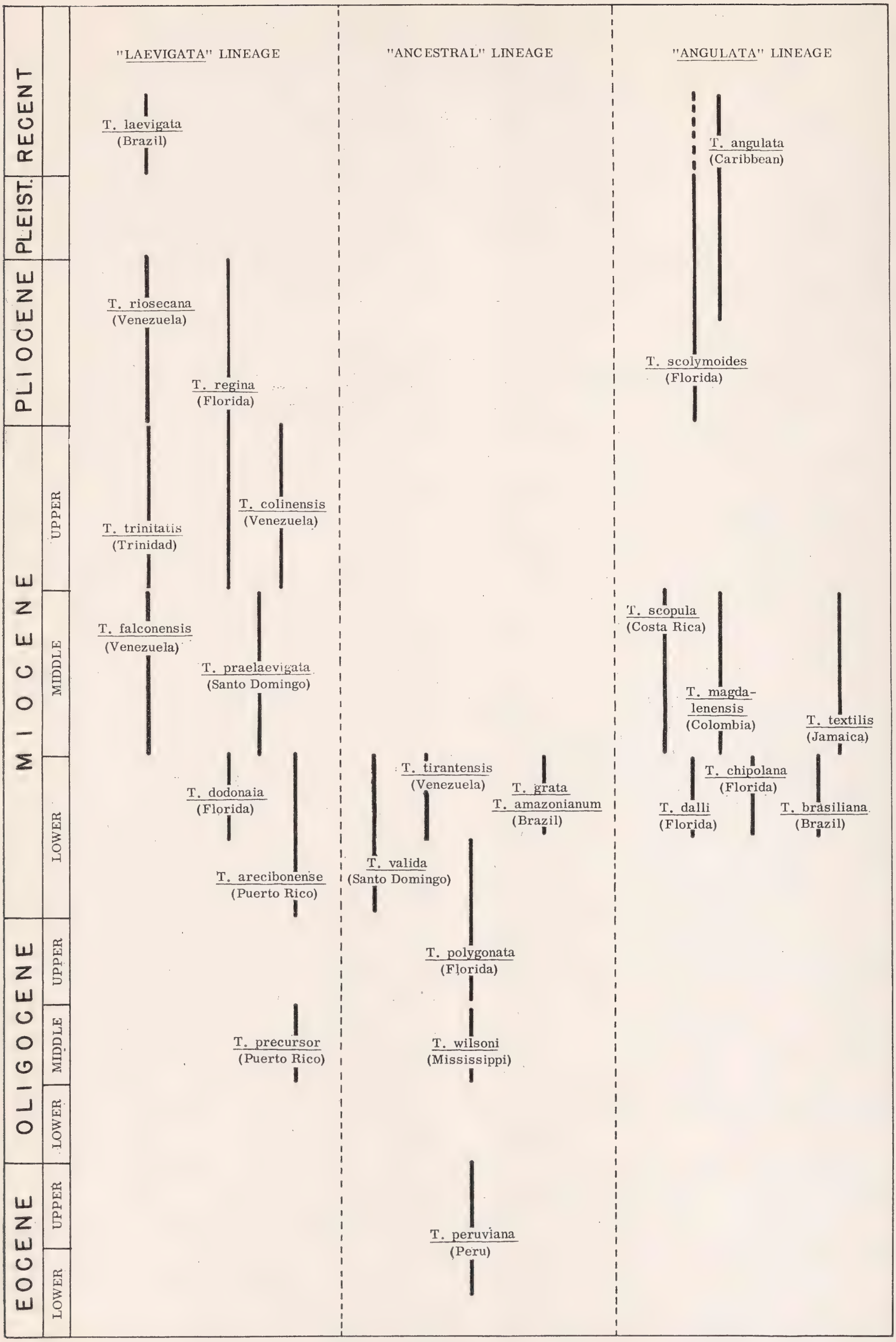

TABLE I
GEOLOGIC AND GEOGRAPHIC DISTRIBUTION OF NEW WORLD SPECIES OF *TURBINELLA*.
(Vertical scale not proportional to absolute time.)

munication between the Indian Ocean and Mediterranean became increasingly obstructed in Miocene times, so that the resemblances between the Indian and Caribbean Miocene faunas are perhaps better explained by migration across the Pacific than across the Atlantic." There is definite need to explain the strong resemblances between the Caribbean and Indian forms which are so strikingly similar, although apparently evolved separately *in situ,* that Vredenburg named a species, from the lower Miocene Gáj beds, *Turbinella praeovoidea* because he considered its descendant in the upper Miocene Mekran beds conspecific with *T. ovoidea* Kiener, the Recent Brazilian species. He subsequently recognized that the Indian line represented only a convergent resemblance and designated the upper Miocene form *T. mekranica. Turbinella praeovoidea,* "the mutation that links *T. mekranica* to the lower Miocene *T. affinis*" (*ibid,* p. 121), he proposed to rename *T. praemekranica.* While this is logical it is not nomenclatorially legal and *T. praeovoidea* must be recognized for the Indian species.

Although Vredenburg considered communication across the Pacific a possible explanation for the extraordinary resemblance between the two lines, the work of Hornell would seem to exclude this possibility. That writer, in attempting to explain variation in the *T. pyrum* group, stated that "deep water is as great a barrier to the dispersal of *Turbinella* as a land barrier, seeing that its larvae do not pass through a free-swimming stage." (1916, p. 120). In both the Old and the New World the earliest species are marked by a noded shoulder which is gradually lost until the form becomes almost smooth. In the Old World the sequence is:

Oligocene—*T. episoma* (Michelotti)
Lower Miocene (Aquitanian)—*T. affinis* J. de C. Sowerby
Lower Miocene (Burdigalian)—*T. praeovoidea* (= *"T. praemekranica"*) Vredenburg and *T. rembangensis* Pannekoek
Upper Miocene—*T. mekranica* Vredenburg
Pliocene—*T. pyrum* (Linnaeus)

In addition to this evolutionary sequence there is a Recent species, *T. fusus* Sowerby, known only from the Andaman Islands, which has retained almost unchanged the characters of its Oligocene ancestor. In Vredenburg's opinion *Turbinella pyrum,* the type of the genus *Turbinella,* does not seem to fit into the evolutionary line and he stated: "There is nothing in the characters of *T. pirum {sic}* that might indicate any close relationship to the line *episoma-mekranica,* and its ancestral predecessors, in the nearer stages at least, must have differed from those of *T. mekranica. T. pirum* is probably an immigrant which, in Pliocene times, invaded the Indian region." (1923, p. 123). However, Hornell (1916) demonstrated convincingly (to this writer, at least) that *T. pyrum* is only an extreme variant of the typical form. In his tremendous work on variation in *Turbinella* he showed that ecology can change the shape of the shell to an almost unbelievable degree. He studied thousands of specimens of *Turbinella pyrum* and found that variation was a result of "the character of the environment, particularly in regard to the degree of exposure to unfavorable conditions, such as surf action, prolonged spells of turbid, mud-laden water, and scarcity of food." (1916, p. 110-111). If this be true, then the validity of many fossil species becomes highly suspect. This fact should be kept in mind at all times. Table I shows the New World species as recognized herein by the author. Many may represent only geographic variants, but for stratigraphic purposes the distinctions will be recognized.

The genus *Turbinella* is a challenging group. Because the specimens are conspicuously large the ratio of described species to existing forms is probably higher than in most genera. It is not a big group and the fossil sequence is reasonably well known. Therefore the evolutionary gradations are indistinct and deciding what constitutes a species or a subspecies becomes particularly difficult. The choice facing the worker is either to accept each variation as a valid species, or to designate almost endless subspecies for all of the forms in each lineage. The shells of *Turbinella* are relatively unornamented and the basis for specific separation is tenuous at best; therefore this writer's decision is to consider each form as a valid species (although often with mental reservations). Vredenburg faced the same problem with the Indian sequence and he concluded: "The close similarity between successive mutations is apt to give rise to some hesitation as to the nomenclature to

be adopted. Any two immediately successive terms of the series might reasonably be treated as varieties of one species, but, if we omit one term, the preceding and the succeeding mutations unhesitatingly convey the impression of distinct species. Under the circumstances we can scarcely adopt any other practical course but to give a separate specific name to each term of the series." (1923, p. 122).

Summary

In the New World two distinct lineages have developed from the ancestral line. One is here termed the *"angulata"* stock, after the Recent representative of the line (the familiar species *T. scolymus* is now known as *T. angulata*). This form is characterized by a more-or-less strongly noded shoulder and a very large nucleus. The second stock, here termed the *laevigata* group after the Recent member of the line (the former *T. ovoidea* is now known as *T. laevigata*!), possesses an almost smooth fusiform shell, and has a relatively smaller nucleus (although still much larger than most gastropods). It is this line which bears the strong resemblance to the Indian series.

The "ancestral" group includes the early species which have a juvenile development unlike either of the above mentioned lineages, but which possess a much smaller protoconch consisting of only one to two whorls, and numerous small ornamented post-nuclear whorls. This line continued through the lower Miocene, coexisting with the two derivative lineages for a time. The genus as a whole reached its greatest development during the Miocene with the majority of the known species occurring during this period (see table I).

The recent species of *Turbinella* from both the New World and the Old World are shallow water, tropical, marine dwellers. It is apparent that the fossil species had a similar environment. The group is carnivorous, feeding on bivalves and tube worms (Hornell, 1916, p. 116; Abbott, 1950, p. 206), and therefore prefers the silty bottom inhabited by these forms. This preference is reflected in the lithology of the Tertiary formations in which the fossil species occur. The majority of these formations are fine, silty sands, clearly of shallow water origin. The most northern occurrence of the genus is in the Oligocene of Mississippi and southern Georgia, suggesting that the tropical seas extended to that latitude during Oligocene time.

III. Acknowledgments

The author would like to express her gratitude to Katherine V. W. Palmer, Director of the Paleontological Research Institution, for the generous loan of the many type specimens of *Turbinella* in the collections of that institution. In the interest of continuity, the type and figured specimens from this paper are also deposited at the Paleontological Research Institution. She thanks the following persons for information supplied on other type material: L. R. Cox, of the British Museum (Natural History); P. E. de Oliveira, of the Divisao de Geologia e Mineralogia, Rio de Janeiro, Brazil; W. Storrs Cole, of Cornell University; Horace G. Richards, of the Academy of Natural Sciences of Philadelphia; Robert Chambers, of the Wagner Free Institute of Science; and Norman D. Newell, of The American Museum of Natural History. She would also like to thank G. Arthur Cooper, of the United States National Museum, for the loan of specimens. Special thanks go to A. N. Dusenbury, Jr., who provided important information on the stratigraphic assignments of certain Venezuelan species. Finally she would like to thank the members of the editorial committee, Katherine V. W. Palmer, Norman E. Weisbord, and Rolf F. Rutsch for their assistance.

Explanation of Symbols

PRI—Paleontological Research Institution

USNM—United States National Museum

USGS—United States Geological Survey

WFIS—Wagner Free Institute of Science, Philadelphia

ANSP—Academy of Natural Sciences of Philadelphia

MPEG—Museu Paraense Emilío Goeldi, Belem, Brazil

DGM—Divisao de Geologia e Mineralogia, Rio de Janeiro, Brazil

Cornell—Cornell University, Ithaca, New York

TU—Tulane University

IV. Systematic Descriptions

Phylum Mollusca

Class Gastropoda

Subclass Prosobranchia
(or Streptoneura)

Order Neogastropoda (or Stenoglossa)

Suborder Rachiglossa

Superfamily Volutacea

Family Turbinellidae

Subfamily Turbinellinae

Genus Turbinella Lamarck, 1799

Xancus Röding, 1798, Museum Boltenianum, p. 134 (placed on Official Index of Rejected and Invalid Generic Names, ICZN Opinion 489, 1957*).
Type species: *Voluta pyrum* Linnaeus, by subsequent designation, Dall, 1906, Jour. Conch., v. 11, p. 296.

Turbinella Lamarck, 1799, Mém. Soc. Hist. Nat. Paris, v. 1, p. 73.
Type species: *Voluta pyrum* Linnaeus, by monotypy.

Turbinellus Lamarck, 1801, Système Animaux sans Vertèbres, p. 83. Emendation?

Scolymus Deshayes, 1843, Animaux sans Vertèbres, ed. 2, v. 9, p. 375. Not *Scolymus* Swainson, 1835.
Type species: *Turbinella scolymus* Lamarck (= *Murex scolymus* Gmelin) by tautonymy.

Mazza H. & A. Adams, 1853, Genera Recent Mollusca, v. 1, p. 156 (*ex* Klein).
Type species: *Voluta pyrum* Linnaeus, by subsequent designation, Abbott, 1950, Johnsonia, v. 2 (28), p. 203.

Turbofusula Rovereto, 1900, Atti R. Univ. Genova, v. 15, p. 169.
Type species: *Turbinella fusus* Sowerby, by original designation.

THE "ANCESTRAL" LINEAGE

Turbinella peruviana (Olsson)

Xancus peruvianus Olsson, 1928, Bulls. Amer. Paleont., v. 14, no. 52, p. 89 (135), pl. 21 (26), fig. 5; Olsson, 1930 *ibid.*, v. 17, no. 62, p. 47.

Xancus peruvianus Olsson. H. K. Hodson, 1931, Bulls. Amer. Paleont., v. 16, no. 59, p. 39.

Diagnosis: "Shell large or medium size, solid and heavy; spire about the length of the aperture with 4 plus whorls (the tip broken); whorls narrowly shouldered and the shoulder angle armed with numerous, feeble ribs or nodes, strongest on the spire whorls; the area between the shoulder angle and the suture is slightly concave or excavated and with an appressed band or feeble cord about the suture; below the shoulder, the sides of the spire-whorls are straight; the side of the body-whorl is straight, contracted in the region of the base and then prolonged into the long, anterior canal; sculpture as noted, consists of feeble ribs or nodes on the shoulder angle, roughly numbering about 15 to 17 on the last whorl, and weak irregular spiral threads, lacking or subobsolete from the middle and upper part of each whorl, but strong and heavy on the anterior canal; inner lip with a wide, spreading callus and the columella is provided with three strong plicae, the upper 2 being stronger.

"Height 85 mm; diameter 47 mm." (Olsson, 1928).

Holotype: PRI 3690.

Horizon: "Restin Sandstone," upper lower Eocene; Saman Formation, upper Eocene; Chira Shale, upper Eocene, Peru.

Discussion: Turbinella peruviana is the oldest known species of *Turbinella* and is clearly ancestral to *T. wilsoni* in the New World Oligocene and probably to *T. episoma* (Michelotti). This latter species occurs in the Oligocene of Italy and of India and gives rise to the species presently known from the Old World. One of these, *T. fusus* Sowerby from the Andaman Islands, is still very much like the Oligocene form, so much so that Vredenburg said: "Whilst, along the coast of western India, the descendants of *T. episoma* constituted a constantly evolving series, it would seem that, in the region of the Andamans, the descendants of *T. episoma* have maintained their original characters almost unchanged to the present day." (1923, p. 123).

The pre-Eocene ancestry of *Turbinella* is not known. Olsson (1930, p. 47) suggested that the genus "probably arose through a *Clavilithes* ancestry in the Eastern Pacific during the Middle Eocene. From this center, it spread during Oligocene and Miocene times through the Caribbean region, to Europe and as far east as India and Java."

Olsson assigned somewhat different ages to the Peruvian formations than are now generally considered correct. Stainforth (1955) summarized the currently accepted chronology and gave the ages cited above for these formations. The "Restin Sandstone" of Olsson is now included in the Cabo Blanco Formation of upper lower Eocene

* See "Appendix I: Nomenclatorial note on the name *Turbinella* Lamarck," at the end of this paper.

age, not middle Eocene as given by Olsson; the Chira Shale is now considered upper Eocene not lower Oligocene.

TURBINELLA WILSONI Conrad

Plate I, figures 1a, 1b

Turbinella wilsoni CONRAD, 1847, Acad. Nat. Sci. Phila., Proc., v. 3, p. 290; CONRAD, 1848, Acad. Nat. Sci. Phila., Jour., (ser. 2) v. 1, p. 120, pl. 12, fig. 12.
Mazza wilsoni (Conrad). CONRAD, 1865, Amer. Jour. Conch., v. 1, p. 23.
Turbinella wilsoni Conrad. DALL, 1890, Wagner Free Inst. Sci., Trans., v. 3, pt. 1, p. 96.
Xancus wilsoni (Conrad). MAURY, 1902, Bulls. Amer. Paleont., v. 3, no. 15, p. 73 (383); MAURY, 1917, *ibid.*, v. 5, no. 29, p. 83 (247); MAURY, 1925, Serv. Geol. Min. Brasil, Mon. 4, p. 154-155.
Not *Xancus wilsoni* (Conrad). DALL, 1916, U. S. Natl. Mus., Proc., v. 51, p. 505 (= *T. polygonata* Heilprin).
Xancus wilsoni (Conrad). PILSBRY and JOHNSON, 1917, Acad. Nat. Sci. Phila., Proc., v. 69, p. 167.
Xancus wilsoni (Conrad). HUBBARD, 1921, N. Y. Acad. Sci., Sci. Surv. Porto Rico & Virgin Islands, v. 3, pt. 2, p. 155.
Xancus wilsoni (Conrad). COOKE, 1922, U.S.G.S. Prof. Paper 129-E, p. 83.
Turbinella wilsoni Conrad. VREDENBURG, 1923, Geol. Surv. India, Records, v. 55, pt. 2, p. 126.
Xancus wilsoni (Conrad). WOODRING, 1928, Carnegie Inst. Washington, Publ. 385, p. 252.
Xancus wilsoni (Conrad). OLSSON, 1928, Bulls. Amer. Paleont., v. 14, no. 52, p. 89 (135); OLSSON, 1930, *ibid.*, v. 17, no. 62, p. 47.
Not *Xancus wilsoni* (Conrad). TUCKER and WILSON, 1933, Bulls. Amer. Paleont., v. 18, no. 66, p. 10 (72), pl. 1 (10), fig. 10 (= *T. regina* Heilprin).
Xancus wilsoni (Conrad). MANSFIELD, 1937, Florida Geol. Surv., Bull. 15, p. 112.
Turbinella wilsoni Conrad. GARDNER, 1944, U.S.G.S. Prof. Paper 142-G, p. 440.

Diagnosis: "Fusiform; spire elevated, acute, volutions ten, angular, nodose, the larger volutions somewhat concave above; the upper volutions with revolving lines, obsolete or wanting on the lower ones; beak with coarse, slightly raised revolving lines; aperture narrow; columella with three rather distinct compressed plaits, the middle one largest; canal long. Length 5 inches.

"The young of this species has distinct lines on every part of the shell, except on the large portion of the body whorl, where they are indistinct and remote. This species is named to commemorate the scientific zeal of Dr. Thomas B. Wilson. It is rare and generally very imperfect." (Conrad, 1847).

Dimensions of lectotype: height 119.5 mm, diameter 46.5 mm.

Lectotype: ANSP 13476 (selected by Moore, 1962, after MacNeil MS).

Horizon: Vicksburg Group, Mississippi. Middle Oligocene.

Figured specimens: Fig. 1a, USNM 644-570; height 120 mm (incomplete), diameter 57 mm; locality, Vicksburg, Mississippi. Fig. 1b, USNM 644571; height 44 mm, diameter 13 mm; locality, Byram, Mississippi. Other occurrences: TU locality no. 334.

Discussion: This species from the Vicksburg beds differs from its southern ancestor, *T. peruviana,* in the greater elongation of the shell, and in having a more sloping shoulder. Although it has been reported from post-Vicksburg localities, these reports seem all to be misidentifications and it ap-

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PLATE I

Figures Page

1. *Turbinella wilsoni* Conrad 44
   a. USNM 644570; height 120 mm (incomplete), diameter 57 mm (X 1)
      Locality: Vicksburg, Mississippi.
   b. USNM 644571; height 44 mm, diameter 13 mm (X 2)
      Locality: Byram, Mississippi.

2. *Turbinella dodonaia* (Gardner) 50
   a. PRI 26909; height 210 mm, diameter 80 mm (X ¾)
      Locality: TU 549. Chipola Formation.
   b. PRI 26910; height 17 mm, diameter 9 mm (X 2)
      Locality: TU 458. Chipola Formation.
   c. PRI 26911; height 47 mm, diameter 17 mm (X 1½)
      Locality: TU 459. Chipola Formation.

PLATE I

parently is confined to the middle Oligocene.

T. wilsoni is the oldest species of which the nature of the nuclear whorls is known. It is assumed that the older form was comparable. The nucleus of *T. wilsoni* is much smaller than either the slender *"laevigata"* type or the larger *"angulata"* type. The smooth nucleus consists of only one and one-half turns followed by several small ornamented post-nuclear whorls, about eight in 20 mm of length. The total number of post-nuclear whorls in an adult shell is about 12. Because of the extreme difference in the early development these older species are not included in either the *"laevigata"* or *"angulata"* lineage but are placed in an "ancestral" position. Presumably the slender *"laevigata"* line is more nearly a direct descendant of the ancestral type than the *"angulata"* line which would seem to be a distinct side development.

Turbinella polygonata Heilprin

Turbinella polygonata Heilprin, 1887, Wagner Free Inst. Sci., Trans., v. 1, p. 108, pl. 15, fig. 43.
Turbinella polygonata Heilprin. Dall, 1890, Wagner Free Inst. Sci., Trans., v. 3, pt. 1, p. 97 (in part).
Xancus polygonatus (Heilprin). Dall, 1915, U. S. Natl. Mus., Bull. 90, p. 63 (in part).
Xancus wilsoni (Conrad). Dall, 1916, U. S. Natl. Mus., Proc., v. 51, p. 505. *Not* of Conrad.
Xancus polygonatus (Heilprin). Pilsbry and Johnson, 1917, Acad. Nat. Sci. Phila., Proc., v. 69, p. 167.
Turbinella polygonata Heilprin. Pilsbry, 1922, Acad. Nat. Sci. Phila., Proc., v. 73, p. 343.
Turbinella polygonata Heilprin. Vredenburg, 1923, Geol. Surv. India, Records, v. 55, pt. 2, p. 127.
Xancus polygonatus (Heilprin). Mansfield, 1937, Florida Geol. Surv., Bull. 15, p. 15, 111, pl. 3, fig. 8.
Xancus polygonatus suwannensis Mansfield, 1937, Florida Geol. Surv., Bull. 15, p. 112, pl. 3, fig. 9.
Turbinella polygonata Heilprin. Gardner, 1944, U.S.G.S. Prof. Paper 142-G, p. 440.

Diagnosis: "Shell elevated, turreted; whorls abruptly flattened on the shoulder—rendering the spire scalariform—the upper ones gently convex, obscurely noded or costated; body-whorl quadrangular, with a broad, flat shoulder; the costae obsolete, resolved into a number (about eight) of shoulder-nodes, which break the circumferential outline into a polygon; aperture greatly exceeding the spire in length; columellar folds three, transverse, situated immediately below the body of the shell; revolving lines of surface feebly defined, almost obsolete on the body-whorls, except on the siphonal tract, where they are well-marked, and of equal significance.

"Length (of fragment, lacking probably two-thirds of an inch below, and a third of an inch above), 1.8 inch; width, .8 inch." (Heilprin, 1887)

"Shell rather large, turreted, with acute spire and large body whorl. Nucleus and earliest post-nuclear whorls not preserved. The earliest 2 or 3 preserved post-nuclear whorls are more slender than the following and show spiral sculpture. The following whorls rapidly enlarge, gently slope anteriorly from the suture, and are strongly shouldered and bear at the periphery moderately strong nodules. Body whorl weakly concave in the area of the anal fasciole, bears about 12 (estimated) nodules on the shoulder, constricted at the base and ornamented on the base and canal with spiral cords. . . . Length 125 mm; greatest diameter 65 mm." (Mansfield, 1937)

Holotype: WFIS 872 *(T. polygonata);* USNM 495943 *(T. polygonata suwannensis).*

Horizon: Flint River Formation and Suwannee Limestone, upper Oligocene; Tampa Limestone, lowermost Miocene. Florida and Georgia.

Discussion: There are no known specimens of *T. polygonata* which have the nuclear whorls preserved, so that for the present time it is also placed in the "ancestral" group with *T. wilsoni,* to which it bears a strong resemblance. It may be distinguished from *T. wilsoni* by the lower spire and slightly more inflated aspect of the younger species.

Mansfield described a subspecies of *T. polygonata* which he called *suwannensis.* Comparison of the type of his subspecies with specimens of *T. polygonata* fails to reveal any distinguishing characteristics. The type specimen of *T. polygonatus suwannensis* is much larger than any specimens yet found of *T. polygonata* s.s. but this does not seem to be a valid distinguishing criterion if the evidence from other species is reliable. It is expected that *T. polygonata* should attain a size similar to that indicated by the specimen of *T. suwannensis.* Both the species which precede it and those which succeed it reach a length of approximately 150 mm.

Turbinella grata (Maury)

Xancus gratus Maury, 1925, Serv. Geol. Min. Brasil, Mon. 4, p. 152-153, pl. 7, fig. 4.
Xancus gratus Maury. Ferreira and Cun-

HA, 1957, Mus. Paraense Emílio Goeldi, Bol.; Geologia No. 2, p. 35.

Diagnosis: "Shell characterized by strongly shouldered whorls with tuberculated riblets. On the last volution there are about ten of the tubercles on the shoulder. The surface of the shell is delicately spirally striated, the striae fading out towards the base. Columella with three transverse plications, the two posterior stronger, the anterior weaker. These folds appear in reverse on the mold as sharp, narrow grooves. Length 70 mm, width 27 mm." (Maury, 1925)

Holotype: DGM 569.

Horizon: Pirabas Limestone, uppermost lower Miocene. Pará, Brazil.

Discussion: From Maury's illustration this species seems to be an immature specimen closely related to *T. polygonata.* It shows a strongly noded shoulder, somewhat more sloped than that of *T. polygonata,* with a less constricted body whorl. The overall shape is more elongate, reminiscent of *T. wilsoni,* and the species probably represents a southern offshot of the original line.

TURBINELLA AMAZONIANUM (Ferreira and Cunha)

Xancus amazonianum FERREIRA and CUNHA, 1957, Mus. Paraense Emílio Goeldi, Bol.; Geologia No. 2, p. 35, pl. 2, figs. 7, 8.

Diagnosis: "Shell of large size, moderately elongated and pointed at the apex. The last whorls, just at the very end, are ornamented by very delicate, almost imperceptable striations. On the apical whorls we find insignificant nodes, or costulate tubercles, which are poorly discerned. In the general aspect, the shell is obesely fusiform, heavy, and has clear whorls with distinct sutures, as in *Xancus validus* (Sowerby, 1849), of the Miocene of Santo Domingo. The whorls are 8 to 10 in number, thickened and wide at the base, gradually becoming thinner toward the apex. They are strongly contorted, superposed, with sharp and distinctly sulcate sutures. They present a smooth slope, wider in the larger whorls, delicately diminishing to the point of disappearing when the last whorls appear. The surface of the slope shows thin axial lines, principally on the larger whorls. On the body of the whorls there is, between one suture and another, one delicate, slightly sulcate line, which accompanying the former, directs itself toward the apex." (Ferreira and Cunha, 1957, *translated*)

Holotype: MPEG 363-I.

Horizon: Pirabas Limestone, uppermost lower Miocene, Pará, Brazil.

Discussion: This species is compared, by the authors, with *T. validus* and with *T. textilis jamaicensis* "Pilsbry and Johnson." However it is not compared with Maury's *T. grata* which is also from the Pirabas Limestone. *T. amazonianum* may very well be the adult form of *T. grata.* The general outline of the shells is identical and the description of the surface ornamentation seems strikingly parallel. Because both species were described from fragmentary material absolute proof is lacking, and for this reason the two species are not placed in synonymy at this time.

TURBINELLA VALIDA Sowerby

Text figure 1

Turbinellus validus SOWERBY, 1850, Geol. Soc. London, Quart. Jour., v. 6, p. 50.

Turbinellus validus Sowerby. GUPPY, 1866, Geol. Soc. London, Quart. Jour., v. 22, p. 575; GUPPY, 1876, *ibid.*, v. 32, p. 523.

Turbinella valida Sowerby. GABB, 1873, Amer. Phil. Soc., Trans., (N.S.) v. 15, p. 218.

Turbinellus validus Sowerby. GUPPY, 1910, Agri. Soc. Trinidad and Tobago, Paper no. 440, p. 6, 9 (*ex* Harris reprint: Bulls. Amer. Paleont., 1921, v. 8, no. 35, p. 149 (297) & 151 (299).)

Xancus validus (Sowerby). MAURY, 1917, Bulls. Amer. Paleont., v. 5, no. 29, p. 83 (247), pl. 13 (39), fig. 5; MAURY, 1925, Serv. Geol. Min. Brasil, Mon. 4, p. 154-155.

Xancus rex PILSBRY, and JOHNSON, 1917, Acad. Nat. Sci. Phila., Proc., v. 69, p. 167.

? Not *Xancus validus* (Sowerby). HUBBARD, 1921, N. Y. Acad. Sci., Sci. Surv. Porto Rico & Virgin Islands, v. 3, pt. 2, p. 155 (? = *T. arecibonense* Hubbard).

Not *Xancus validus* (Sowerby). PILSBRY, 1922, Acad. Nat. Sci. Phila., Proc., v. 73, p. 342, pl. 25, fig. 3 (? = *T. textilis* Guppy).

Xancus rex Pilsbry and Johnson. PILSBRY, 1922, Acad. Nat. Sci. Phila., Proc., v. 73, p. 342, pl. 26, figs. 5, 8.

Xancus validus (Sowerby). OLSSON, 1922, Bulls. Amer. Paleont., v. 9, no. 39, p. 112 (284).

Turbinella valida Sowerby. VREDENBURG, 1923, Geol. Surv. India, Records, v. 55, pt. 2, p. 125.

Turbinella rex (Pilsbry and Johnson). VREDENBURG, 1923, Geol. Surv. India, Records, v. 55, pt. 2, p. 127.

Xancus rex Pilsbry and Johnson. WOODRING, 1928, Carnegie Inst. Washington, Publ. 385, p. 251.

Xancus validus (Sowerby). WOODRING, 1928, Carnegie Inst. Washington, Publ. 385, p. 252.

Xancus rex Pilsbry and Johnson. WEISBORD, 1929, Bulls. Amer. Paleont., v. 14, no. 54, p. 47 (279).

Xancus aviaguensis H. K. HODSON, 1931,

Bulls. Amer. Paleont., v. 16, no. 59, p. 38, pl. 19, fig. 2.

Xancus rex Pilsbry and Johnson. MANSFIELD, 1937, Florida Geol. Surv., Bull. 15, p. 15, 112.

Xancus validus (Sowerby). FERREIRA and CUNHA, 1957, Mus. Paraense Emílio Goeldi, Bol.; Geologia No. 2, p. 25.

Diagnosis: "Testa oblongo-subfusiformis, laevis, postice acuminata, antice coarctata, anfractibus 6 ad 8, subventricosis, spiraliter striatis, posticis transversim obtuse costatis, intermediis subtuberculatis, anticis duobus postice tuberculatis; suture canaliculata, margine levata; apertura magna, canali valido extus striato.

Text figure 1. *Turbinella valida* Sowerby (X 1).
Lectotype: British Museum (Nat. Hist.) GG. 20212.

"This species somewhat resembles *T. scolymus;* it differs, however, materially in its general form not being hexagonal; in the suture, whose margin is elevated and with a narrow channel; and in its tubercules, which are small and rounded." (Sowerby, 1850)

"The shell is biconic, large and ponderous, the periphery about median. First whorl distorted, bulbous, smooth, next whorl contracted and narrow. Succeeding whorls have massive axial folds, 6 or 7 on a whorl, traversed by about 7 spiral cords. After the mid-neanic stage the spiral sculpture weakens, and the folds gradually give place to strong tubercles at the shoulder. On the last whorl of the type there are 12 such tubercles. Above the shoulder there is a steep, slightly concave slope to the suture, the surface being conspicuously, finely plicate and having a few spiral cords, which are indistinct in the adult stage. The whorl is appressed at the suture, the axial wrinkles becoming strongly retractive laminae there. The basal half of the last whorl has many spiral cords. The inner lip is heavily calloused, columella with 3 strong plaits. (Pilsbry and Johnson, 1917 [*T. rex*])

Dimensions of lectotype: height 130 mm (incomplete), diameter 57 mm.

Lectotype (here designated, after Sherborn): British Museum (Nat. Hist.)—GG. 20212. Formerly London Geol. Soc. Coll. 12819.

Horizon: ? Baitoa Formation, lower Miocene (Woodring, 1928, p. 252). Dominican Republic.

Figured specimen: Text figure 1, GG. 20212 (lectotype); height 130 mm, diameter 57 mm. Photograph courtesy of British Museum (Nat. Hist.).

Discussion: Pilsbry (1922, p. 342) stated that the common species from the Miocene beds of Santo Domingo, referred to *T. validus* by Gabb, Maury, and other authors, was actually the species *T. rex.* This latter species, he declared, differed from *T. validus* in that the spire was more elevated and the nodes more pronounced. He also figured a specimen which he identified as *T. validus.* Comparison of that figure with photographs of syntypes of Sowerby's species shows that Pilsbry's specimen is not *T. validus,* but is a different species closely related to, if indeed not conspecific with, *T. textilis* (Guppy). The figures of the type specimen of *T. rex,* on the other hand, clearly indicate that *T. rex* is the same as *T. validus.*

No specimen of *T. validus* has ever been figured, and apparently the holotype is lost. Dr. L. R. Cox, of the British Museum (Natural History) has kindly provided the writer

with a photograph of the specimen selected by Sherborn as "lectotype," although this selection was never published as such. In the "List of Types and Figured Specimens in the Collection of the Geological Society of London," this specimen was listed as R 12819 (Blake, 1902, p. 65). The collection subsequently went to the British Museum (Natural History) and this specimen is there catalogued as GG.20212.

T. validus is much like *T. wilsoni,* differing only in a greater elongation of the shell. Therefore *T. validus* is included in the "ancestral" group. It is not in the direct line of descent toward either the *"laevigata"* or the *"angulata"* stocks, but presumably is an end member of the "ancestral" line.

T. aviaguensis Hodson was described from the "Upper Middle Oligocene" near Dabajuro, Falcón, Venezuela. The stratigraphic assignment of this species as well as all of the other Hodson species is a matter of guesswork, for in the original publication only a locality and an age assignment were given, and most of the ages must be revised upward in the light of present knowledge. A. N. Dusenbury, Jr., has been working on the problem, and has provided the information *(in litt.)* that *T. aviaguensis* apparently comes from the Cauderalito Member (Aquitanian) of the lower Miocene Agua Clara Formation. In view of the strong resemblance of the shell of *T. aviaguensis* to that of *T. valida,* combined with the almost simultaneous geologic occurrence, the two species are placed in synonymy.

Turbinella tirantensis (H. K. Hodson)

Xancus tirantensis H. K. Hodson, 1931, Bulls. Amer. Paleont., v. 16, no. 59, p. 39, pl. 21, figs. 1-3.

Diagnosis: "The shell is of medium size, with shouldered, straight-sided whorls. The very young stages are unknown, but the neanic whorls carry 6 or 7 longitudinal nodes and several spiral threads. The spiral threads continue a short distance beyond the nodes, but soon become obsolete. After the nodes disappear, the whorls are shouldered with a narrow presutural band, which is not excavated and only obsoletely noded, if at all; sometimes this band forms a sharp corded shoulder and sometimes a rounded shoulder. Below the shoulder, the whorls are straight-sided and almost smooth; the anterior canal carries spiral cords.

"This species resembles *X. peruvianus* Olsson, but the sutures of the Venezuelan form are more excavated, the sutural band is flatter and less noded, and the spiral cords of the anterior canal are smaller." (Hodson, 1931)

Dimensions of holotype: height 87 mm (incomplete), diameter 60 mm.

Holotype: PRI 24109.

Horizon: Agua Clara Formation, lower Miocene. Dist. of Buchivacoa, Falcón, Venezuela.

Diagnosis: The type material of this species is very poorly preserved, making it difficult to affiliate with other species. The single distinguishing characteristic seems to be a pronounced ridge at the shoulder which is similar to that of *T. valida.* As with *T. aviaguensis* the stratigraphic assignment is subject to question, however, Dusenbury places this species *(in litt.)* in the Santiago Member (Burdigalian) of the lower Miocene Agua Clara Formation. Thus *T. tirantensis* is somewhat younger than *T. aviaguensis,* presumably its nearest relative. It is possible that *T. tirantensis* is also synonymous with *T. valida,* but until better material is available little can be done with this species.

THE *"LAEVIGATA"* LINEAGE

Turbinella precursor Hubbard

Turbinella chipolana variety *precursor* Hubbard, 1921, N. Y. Acad. Sci., Sci. Surv. Porto Rico & Virgin Islands, v. 3, pt. 2, 153, pl. 23, figs. 6, 7.

Xancus precursor (Hubbard). Woodring, 1928, Carnegie Inst. Washington, Publ. 385, p. 251.

Diagnosis: "Shell small, fusiform, consisting of three and one-half nuclear whorls and three post-nuclear whorls; protoconch like *T. chipolana* Dall and *T. regina* Heilprin, in having a swollen tip, succeeded by smaller nuclear whorls. The tip consists of one and one-half volutions, is transversely ovate, and is peculiar in having a shallow median constriction. The two succeeding nuclear whorls considerably smaller in diameter, the first being gently convex, the last nearly flat. The latter is succeeded abruptly by sculptured whorls with seven rounded, not nodose ribs, and prominent spirals, of which there are four on the first two, and about twenty-three on the final whorl and pillar. The spirals are separated by wider interspaces. The whorls are marked by a prominent, narrow and wavy sub-sutural band or shoulder, sculptured with at first one and later with two spirals. The interspace immediately below the shoulder is strongly impressed. The spirals are of equal strength, except on the pillar, where faint intercalated threads appear. The entire post-

nuclear surface is marked by fine raised longitudinal growth lines, strongest in the interspaces between the spirals. Height of shell 17.5 mm, maximum diameter 7 mm; height of protoconch 3½ mm, diameter of tip of protoconch 2½ mm." (Hubbard, 1921)

Holotype: Not found.

Horizon: San Sebastion Shale, middle Oligocene. Lares Dist., Puerto Rico.

Discussion: Although Hubbard considered the type material of this species adult, it is obvious that the shell is a juvenile form. He compared both this species and the following one, *T. arecibonense,* to *T. chipolana;* however, the smaller protoconch and more slender shape suggest that their true affiliation is with *T. dodonaia.* If this is the case *T. precursor* is the oldest known species of the *"laevigata"* line. Unfortunately the type material, which was poor to begin with, seems to be lost, and one must await discovery of better material before this conjecture can be proved or disproved.

Turbinella areciboense Hubbard

Turbinella chipolana variety *areciboense* Hubbard, 1921, N. Y. Acad. Sci., Sci. Surv. Porto Rico & Virgin Islands, v. 3, pt. 2, p. 154, pl. 23, fig. 8.

Diagnosis: "A single specimen in which the lower half of the body whorl is missing. Protoconch like that of variety *precursor,* but without median construction [*sic*] of the tip, and with the third whorl almost entirely concealed by the overlapping of the first post-nuclear whorl, giving the appearance of a two-whorl protoconch. The tip is slightly larger (diameter 3 mm) than that of *precursor,* and slightly more swollen when compared with the succeeding whorls. The whorl following the tip is nearly flat, whereas in *precursor* it is noticeably convex. The first post-nuclear whorl has ribs, spirals, and sub-sutural band, or shoulder, as in *precursor* and represents the *precursor* stage. On the next and following whorls, however, the ribs become nodose, and on later whorls there are more spirals than in *precursor,* with occasionally a fine intercalated spiral. The longitudinal growth lines are similar to those of *precursor,* but show a tendency to alternate in strength. The sub-sutural band, or shoulder, is prominent in the first two post-nuclear whorls and marked by a single spiral; on the third whorl it is inconspicuous, and marked by two spirals, as in the later whorls of *precursor,* while on the fourth and fifth (or final) whorls it has disappeared altogether. This fact is interesting in showing the tendency to lose a primitive character which has apparently been completely lost in the Chipolan shell. Height of fragment 20 mm, maximum diameter 11 mm." (Hubbard, 1921)

Holotype: Not found.

Horizon: Quebradillas Limestone, lower Miocene. Lares Dist., Puerto Rico.

Discussion: The type material of this species is not only a juvenile but is also incomplete. Presumably it is the descendant of the middle Oligocene species *T. precursor,* and therefore antecedent to *T. dodonaia,* but until better material is available there is little that can be done with this species. In the same paper Hubbard reported finding "a few fragments" of a species which he referred to *"Xancus validus,"* stating that these fragments showed the sculpture of that species. It is possible that *T. arecibonense* is a synonym of *T. valida,* for the early whorls of the two forms are similar; however, the nature of the nucleus seems to suggest that *T. arecibonense* is more closely allied with the *"laevigata"* line.

Turbinella dodonaia (Gardner)

Plate I, figures 2a, 2b, 2c

Xancus wilsoni (Conrad). Maury, 1902, Bulls. Amer. Paleont., v. 3, no. 15, p. 64 (374). *Not* of Conrad.

? Xancus sp. indet. Maury, 1925, Serv. Geol. Min. Brasil, Mon. 4, p. 154-155, pl. 7, figs. 6, 10.

Xancus dodonaius Gardner, 1944, U.S.G.S. Prof. Paper 142-G, p. 440, pl. 49, fig. 2.

Xancus mauryae Ferreira and Cunha, 1957, Mus. Paraense Emílio Goeldi, Bol.; Geologia No. 4, p. 24, pl. 2, fig. 1.

Diagnosis: "Shell probably very large and heavy, the height of perfect individuals exceeding a foot. Outline rudely fusiform, the maximum diameter approximating the median horizontal. Whorls of conch probably 8 or 9 in number. Outline of the early volutions obscured by the axial costae, the medial whorls narrowly tabulated, flattened laterally or feebly rounded, rudely trapezoidal in outline; the later volutions developing an acute keel a little behind the median line, this shouldered portion becoming increasingly less oblique and in the older individuals, becoming tuberculate. Body flattened medially, smoothly constricted at the base. Protoconch broken away in all available material but probably large at the base. Axial sculpture, with the exception of the incrementals, restricted to the early whorls. Axials on earliest whorls of the conch narrow, rounded, persistent to the posterior suture, probably as many as 10 in number, rapidly becoming broader and evanescing on the closely appressed posterior third, reducing to 7 in number on the third and later volutions, becoming increasingly

broader and lower on each succeeding volution and altogether obsolete near the fifth. Spiral lirae initiated with the axials, sharp and sharply elevated, and from 4 to 6 in number upon the earliest whorls, with 2 or 3 additional lirae developed upon the appressed posterior portion; secondaries intercalated on the third or fourth volution, as in *chipolanus;* spiral sculpture diminishing with the axial but persisting as well defined lirae through another revolution; an obscure spiral shagreening but no well defined liration usually visable on the adult whorls. Base of body, pillar, and fasciole in many individuals finely and rather obscurely threaded. Sutures impressed upon the earlier volutions, feebly channeled upon the later. Aperture obliquely pyriform in outline. Labrum broadly arcuated, not lirate within. Parietal wall heavily glazed, the callus spread in a broad arc from the posterior commissure to the anterior canal. Columella triplicate, the posterior fold placed directly at the base of the body, the outer two approximately equal and parallel to it and almost horizontal near their termination. Anterior canal rather broad, very feebly recurved. Anterior fasciole strongly arched in the adults, corrugated by the incrementals, obliquely truncate or broadly emarginate at its extremity. Umbilicus normally imperforate.

"Dimensions of holotype: Height, 90 millimeters; length of aperture, 55 millimeters; maximum diameter, 34.0 millimeters." (Gardner, 1944)

Holotype: USNM 371439.

Horizon: Oak Grove Sand and Chipola Formation, uppermost lower Miocene. Florida.

Figured specimens: Fig. 2a, PRI 26909; height 210 mm, diameter 80 mm; locality TU 549. Fig. 2b, PRI 26910; height 17 mm, diameter 9 mm; locality TU 458. Fig. 2c, PRI 26911; height 47 mm, diameter 17 mm; locality TU 459. Other occurrences: TU locality nos. 70, 91, 453, 457, 546, 547, 548.

Discussion: The type specimen of *T. dodonaia* although of "mature" aspect is by no means an adult shell, for one specimen from the Chipola River, here figured, measures 210 mm and Gardner reported a specimen which if complete would have measured over 300 mm in length. It seems to be characteristic of the genus *Turbinella* that the animal never reaches a point where it stops growing completely. The shell attains a mature aspect at a fairly early stage and the animal simply continues to grow larger until death overtakes it. Certainly immature or adolescent specimens of any species of *Turbinella* are more common, and one should be wary of declaring any small specimen an "adult."

This species is widespread in the Chipola Formation, but it is never common. Collections usually consist of juveniles and only rarely is a large individual found. This form is clearly ancestral to *T. regina* and the Recent *T. laevigata.* There are a number of intermediate forms in Venezuela and the Caribbean which are also exceedingly like *T. dodonaia* and will be discussed in sequence. Maury (1925) figured two specimens from the Pirabas Limestone of Brazil, correlated with the Chipola Formation, that are very much like *T. dodonaia,* and it is probable they represent this species. More recently Ferreira and Cunha (1957) described *Xancus mauryae* from the Pirabas Limestone which they compared with Maury's specimens and which is most certainly conspecific with *T. dodonaia.*

T. dodonaia occurs with another superficially similar species, *T. chipolana* Dall. The juvenile shell of *T. chipolana* may be distinguished readily from that of *T. dodonaia,* the more common species. *T. dodonaia* is smaller, the nucleus being approximately 2 mm in diameter and proportionally less in length. The nucleus of *T. chipolana* is about 4 mm in diameter and much larger in proportion to the neanic shell than is the delicate *T. dodonaia.* Adult specimens of these two species may be distinguished by the relative slenderness of *T. dodonaia,* and by the smoother shell of that species. *T. dodonaia* loses the neanic nodes and spiral ribs simultaneously on the fourth to fifth post-nuclear whorl and the adult shell is almost completely smooth. Even on the pillar only a faint trace of spiral ornamentation remains. The neanic whorls of *T. dodonaia* retain their axial nodes for a much longer duration than those of *T. chipolana.* The first five post-nuclear whorls of *T. dodonaia* retain the juvenile ornamentation and only subsequently does the shell become smooth. This characteristic is very similar in *T. regina* and the young shells of both species are strikingly alike. In *T. regina* the spiral ribbing is retained for a longer time than in *T. dodonaia.* However, in the upper Miocene forms of *T. regina* the spiral ribbing dies out in an earlier stage than the Pliocene forms, suggesting an evolutionary sequence.

TURBINELLA PRAELAEVIGATA, E. H. Vokes, nom. nov.

Turbinellus ovoidea Kiener. MOORE, 1850, Geol. Soc. London, Quart. Jour., v. 6, p. 40; MOORE, 1853, *ibid.*, v. 9, p. 130. *Not* of Kiener.

Turbinellus ovoideus Kiener. GUPPY, 1866, Geol. Soc. London, Quart. Jour., v. 22, p. 575; GUPPY, 1874, Geol. Mag. (decade 2) v. 1, p. 438 (in part); GUPPY, 1876, Geol. Soc. London, Quart. Jour., v. 32, p. 523. *Not* of Kiener.

Turbinella ovoidea Kiener. GABB, 1873, Amer. Phil. Soc., Trans., (N.S.) v. 15, p. 218. *Not* of Kiener.

Xancus proaevoideus [*sic*] MAURY, 1917, Bulls. Amer. Paleont., v. 5, no. 29, p. 83 (247), pl. 14 (40), fig. 18. Corrected to *praeovoideus* in errata. Not *Turbinella praeovoidea* Vredenburg, 1916.

Xancus praeovoideus Maury. PILSBRY, 1922, Acad. Nat. Sci., Phila., Proc., v. 73, p. 343.

Turbinella praeovoidea (Maury). VREDENBURG, 1923, Geol. Surv. India, Records, v. 55, pt. 2, p. 125. Not *T. praeovoidea* Vredenburg, 1916.

Not *Xancus praevoideus* [*sic*] Maury. MAURY, 1925, Bulls. Amer. Paleont., v. 10, no. 42, p. 207 (359), pl. 38 (49), fig. 1 (= *T. riosecana* Hodson).

Xancus praeovoideus Maury. MAURY, 1925, Serv. Geol. Min. Brasil, Mon. 4, p. 623, pl. 7, fig. 12.

Xancus praeovoideus Maury. H. K. HODSON, 1931, Bulls. Amer. Paleont., v. 16, no. 59, p. 40; H. K. HODSON, 1931, *ibid.*, v. 16, no. 60, p. 13 (107).

Xancus praeovoideus Maury. RUTSCH, 1942, Verh. Naturf. Gesell., Basel, v. 54, p. 162.

Xancus praeovoideus Maury. FERREIRA and CUNHA, 1957, Mus. Paraense Emílio Goeldi, Bol.; Geologia No. 4, p. 27.

Diagnosis: "Our recent shells of *X. ovoidea* collected by the Hartt expedition at Bahia, Brazil, show the spire is spirally striate, *not costate*. In the fossils the spire is *strongly tuberculately costate* for about five whorls, and the three columellar plications are decidedly heavier. Length 178, width 71 mm." (Maury, 1917)

Holotype: Cornell 36829.

Horizon: Cercado Formation, lower Miocene; Gurabo Formation, middle Miocene. Dominican Republic.

Discussion: Xancus praeovoideus was so named by Maury because of its resemblance to the Recent species *T. ovoidea* Kiener (=*T. laevigata*), living off the coast of Brazil. However, almost simultaneously with Maury's work, Vredenburg (1916) gave the same name to a species from the lower Miocene (Burdigalian) Gáj Beds of India, also because of its resemblance to *T. ovoidea.* At the time Vredenburg was of the opinion that the upper Miocene Indian form was conspecific with the Recent Brazilian species, however later (1923, p. 121) he decided that the two were not synonymous, and named the Indian species *T. mekranica.* He then stated, "The mutation that links *T. mekranica* to the lower Miocene *T. affinis* can no longer be known under the misleading name of *praeovoidea* which I now propose to alter to *praemekranica.* As the shell has not been figured, taxonomists may perhaps forgive me this change of nomenclature." He then suggested that because the Santo Domingan fossil was obviously the true ancestor of *T. ovoidea,* "Miss Maury's designation is so excellently suited to the fossil under consideration that we cannot do better than adopt it." (p. 125). Unfortunately the modern rules of nomenclature do not permit such a solution, and Maury's name must be considered as preoccupied by that of Vredenburg. However, as "the Lord giveth and the Lord taketh away," so the Law of Priority has given us another name to replace that of Maury. The familiar name *T. ovoidea* has been found to be a junior synonym of *T. laevigata* Anton; therefore Maury's *T. praeovoidea* is herein transmuted to *T. praelaevigata* and once again stability is established.

This species is one of the more common Santo Domingan fossils. Pilsbry (1922, p. 343) stated that Gabb had collected this shell "in considerable quantity." Maury (1917, p. 84) also stated that "we collected a number of specimens." The shell reaches a length of 200 mm and is consequently a conspicuous element in the fauna at any locality where it occurs. The species was reported from Santo Domingo by all of the early writers, such as Gabb and Guppy, as *"T. ovoidea,"* but as Maury pointed out, the shells differ noticeably. The Recent species also is usually smaller. The largest size reported (Abbott, 1950, p. 207) is 120 mm.

Maury (1917, p. 84) reported finding this species at both Bluff 1 and Bluff 3, Cercado de Mao. Bluff 1 she referred to an "upper" formation, correlated with the Gatun Formation of Panama, and Bluff 3, she referred to a "lower" formation, correlated with the Chipola Formation of Florida (1917, table after p. 459). She subsequently (1919) named these the Gurabo (upper) and the Cercado (lower) Formations, one middle Miocene and the other lower Miocene.

T. praelaevigata is much like *T. dodonaia*

but may be distinguished by a pronounced presutural band or constriction. Moreover, the suture of *T. praelaevigata* is strongly appressed and the spiral ornamentation is much more conspicuous. This species is also closely related to *T. regina,* the upper Miocene-Pliocene member of the line, but may be distinguished by the slightly more inflated form of *T. praelaevigata* as well as by the presutural band.

Turbinella falconensis (H. K. Hodson)

Xancus falconensis H. K. Hodson, 1931, Bulls. Amer. Paleont., v. 16, no. 59, p. 40, pl. 22, figs. 1, 3.

Xancus falconensis Hodson. H. K. Hodson, 1931, Bulls. Amer. Paleont., v. 16, no. 60, p. 13 (107).

Diagnosis: "The shell is of medium size, slender, flat-whorled. The youngest whorls are unknown. The last 3½ neanic whorls are strongly noded longitudinally below a narrow, flat band, which is just in front of the posterior suture; there are 5 or 6 nodes on each whorl; each neanic whorl bears about 5 primary spiral threads, between which secondary spirals rapidly appear and increase in strength as the whorls grow larger. The sculpture of the neanic stage dies out rather abruptly leaving the early adult whorls smooth except for a few, fine, spiral threads; the adult whorls are long, flat-sided, and bear only a trace of the shoulder produced by the posterior sinus. The later adult whorls have practically no spiral threads. The sutures are usually channeled. The posterior sinus is deep and narrow; below this, the lip is flat-sided to its anterior constriction. The mouth measures almost half of the length of the shell in the adult.

"This species is more slender and flatter-whorled than *X. praeovoideus* Maury; on our species the nodes on the neanic whorls and the spiral threads disappear earlier." (Hodson, 1931)

Dimensions of holotype: height 153 mm, diameter 64 mm.

Holotype: PRI 24111.

Horizon: ? Socorro Formation, middle Miocene. Dist. of Falcón, Venezuela.

Discussion: There is a series of three species from the middle Miocene, the upper Miocene, and the Pliocene of Venezuela and Trinidad which are all exceedingly alike. They differ solely in having an increasing degree of inflation of the body whorl. *T. riosecana,* the Pliocene form, is the most inflated; *T. falconensis,* the middle Miocene form, is the least inflated. The line is clearly an almost direct descendant of *T. dodonaia* from the lower Miocene of Florida.

Hodson originally gave the locality of *T. falconensis* as "Cantura, Cocodito area, Paraguaná Peninsula, Dist. of Falcón, Falcón, Venezuela." This was subsequently corrected to "Cantaure, Cocodite area" by Brann and Kent (1960, p. 980). Dusenbury *(in litt.)* places the species in beds approximately equivalent to the Socorro Formation.

Turbinella trinitatis (Maury)

Xancus trinitatis Maury, 1925, Bulls. Amer. Paleont., v. 10, no. 42, p. 208 (360), pl. 39 (50), fig. 1.

Xancus trinitatis Maury. H. E. Vokes, 1938, Amer. Mus. Novitates, no. 988, p. 4.

Xancus trinitatis Maury. Rutsch, 1942, Verh. Naturf. Gesell., Basel, v. 54, p. 162, pl. 9, figs. 2, 4.

Diagnosis: "Shell exceedingly large and heavy, differing in contour from *praeovoideus,* the shape being more fusiform, the body proportionately longer and less wide and all the volutions less convex. The very early whorls are lacking, but below the last striated volution the first whorls are slightly but clearly carinate below the suture. All the shells are incomplete, but the largest is 255 mm long and when entire would measure 300 x 100 mm." (Maury, 1925)

Holotype: PRI 1117.

Horizon: Springvale Beds, upper Miocene. Trinidad.

Discussion: T. trinitatis is the middle member of the sequence discussed under *T. falconensis* and is only slightly less inflated than the Pliocene *T. riosecana.* In all of these species we are hampered by a lack of specimens with which to establish the range of variation. Studies of *T. regina* (see discussion following) suggest that the length/width ratio is fairly constant and that these three forms are probably good stratigraphic subspecies if nothing more. *T. regina* is closely related to this line but is more slender than any of the southern species.

Turbinella riosecana (H. K. Hodson)

Turbinellus ovoideus Kiener. Guppy, 1866, Geol. Soc. London, Quart. Jour., v. 22, p. 576; Guppy, 1874, Geol. Mag. (decade 2) v. 1, p. 438 (in part). *Not* of Kiener.

Turbinelus [*sic*] *ovoideus* Kiener. Guppy, 1910, Agri. Soc. Trinidad and Tobago, Paper no. 440, p. 6 (*ex* Harris reprint: Bulls. Amer. Paleont., 1921, v. 8, no. 35, p. 149 (297).) *Not* of Kiener.

Xancus praevoideus [*sic*] Maury. Maury,

1925, Bulls. Amer. Paleont., v. 10, no. 42, p. 207 (359), pl. 38 (49), fig. 1. *Not* of Maury, 1917.

Xancus praeovoideus riosecanus H. K. Hodson, 1931, Bulls. Amer. Paleont., v. 16, no. 60, p. 12 (106), pl. 11 (35), fig. 1; pl. 12 (36), fig. 1.

Xancus praeovoideus Maury. H. E. Vokes, 1938, Amer. Mus. Novitates, no. 988, p. 4. *Not* of Maury, 1917.

Xancus trinitatis riosecanus H. K. Hodson. Rutsch, 1942, Vehr. Naturf. Gesell., Basel, v. 54, p. 161, pl. 9, figs. 1, 3.

Diagnosis: "This is a large, fat species. The last whorl of the neanic stage is about the youngest one preserved on the present specimens; it carries 7 longitudinal nodes and about 6 primary spiral threads. The transition from the neanic to the adult stage is rather gradual, leaving the first adult whorls with faint primary spirals and in some instances with a poorly developed keel at the edge of the presutural band. The larger whorls are practically smooth, and a large shell has a proportionately greater diameter than a young shell. The columella bears only 3 folds." (Hodson, 1931)

Dimensions of holotype: height 172 mm, diameter 93 mm (not 101 mm, as stated by Hodson).

Holotype: PRI 24148.

Horizon: Springvale Beds, upper Miocene, Trinidad. Rio Seco Formation, Pliocene, Falcón, Venezuela.

Discussion: The locality given by Hodson for *T. riosecana* is approximately 20 km northeast of Urumaco, Falcón, Venezuela. According to Dusenbury *(in litt.)* the species occurs in the Rio Seco Formation of Pliocene age. *T. riosecana* is the third member of the sequence just discussed. The inflation of the shell increases successively from oldest to youngest species, with *T. riosecana* being the most inflated of the three. If this tendency toward increasing "plumpness" represents an "orthogenetic" trend then this line is probably directly ancestral to the Recent *T. laevigata,* the most inflated form of of the sequence.

Maury (1925) reported *Xancus praevoideus {sic}* from the Springvale beds of Trinidad. However the specimen which she figured is much more inflated than *T. praeovoidea* (=*T. praelaevigata,* nom. nov.) and does not seem to be nearly as close to the Santo Domingan species as does the second species that she described at the same time, *Xancus trinitatis.* Rutsch (1942) figured a similar specimen under the name *Xancus trinitatis riosecanus,* recognizing the Trinidad *"praeovoideus"* to be the same as the Venezuelan *X. praeovoideus riosecanus* Hodson. Because the name *T. praeovoidea* (Maury) is preoccupied by that of Vredenburg he placed the subspecies in *T. trinitatis* rather than the Santo Domingan *T. praeovoidea* to which it originally had been referred by Hodson.

Turbinella colinensis (H. K. Hodson)

Xancus colinensis H. K. Hodson, 1931, Bulls. Amer. Paleont., v. 16, no. 59, p. 40, pl. 21, fig. 4.

Diagnosis: "This species is small, unless the specimens found as yet are all young, and easily recognized. The shell is slender, noded throughout its length and ornamented with fine spiral lines. The youngest whorls are unknown; the neanic whorls carry 5 nodes (sometimes 6), and about 7 spiral threads. As the shell grows, the spiral threads become more numerous and the longitudinal nodes gradually less prominent, although there is no marked difference or marked boundary between the neanic and adult whorls. The presutural band is flat or only slightly excavated, and the whorls are flat-sided except for the nodes." (Hodson, 1931)

Dimensions of holotype: height 73 mm, diameter 27.7 mm.

Holotype: PRI 24110.

Horizon: La Vela Formation, upper Miocene. Dist. of Colina, Falcón, Venezuela.

Discussion: Once again as in the other Hodson species, the horizon is a matter of guesswork; however, in this case the task is simplified by the fact that the type locality of the species is the same as the type locality of the La Vela Formation of upper Miocene age (Liddle, 1942, p. 496).

This species is undoubtedly described from immature individuals, for the type specimen is very much like the young of *T. regina* of similar size. There are certain observable differences, however, and they are not believed to be identical. The nodes on the neanic whorls of *T. colinensis* are relatively stronger and persist longer than do those of *T. regina.* Although this species occurs in the same stratigraphic position as *T. trinitatus,* it is apparently not just the juvenile form of this species, as might be suspected from first glance. *T. colinensis* may be distinquished by the retention of the early neanic nodes to a later stage of development.

TURBINELLA REGINA Heilprin

Plate III, figures 3a, 3b

Turbinella regina HEILPRIN, 1887, Wagner Free Inst. Sci., Trans., v. 1, p. 74, pl. 3, fig. 5.
Turbinella regina Heilprin. DALL, 1890, Wagner Free Inst. Sci., Trans., v. 3, pt. 1, p. 98, pl. 3, fig. 4.
Turbinella regina Heilprin. HUBBARD, 1921, N. Y. Acad. Sci., Sci. Surv. Porto Rico & Virgin Islands, v. 3, pt. 2, p. 154.
Turbinella regina Heilprin. PILSBRY, 1922, Acad. Nat. Sci. Phila., Proc., v. 73, p. 343.
Turbinella regina Heilprin, VREDENBURG, 1923, Geol. Surv. India, Records, v. 55, pt. 2, p. 126.
Xancus wilsoni (Conrad). TUCKER and WILSON, 1933, Bulls. Amer. Paleont., v. 18, no. 66, p. 10 (72), pl. 1 (10), fig. 10. *Not* of Conrad.
Xancus reginus (Heilprin). GARDNER, 1944, U.S.G.S. Prof. Paper 142-G, p. 439.
Xancus regina (Heilprin). OLSSON and HARBISON, 1953, Acad. Nat. Sci. Phila., Mon. 8, p. 195, pl. 24, fig. 6; pl. 37, fig. 9.
Xancus regina (Heilprin). DUBAR, 1958, Florida Geol. Surv., Bull. 40, p. 190, pl. 10, fig. 9.

Diagnosis: "Shell ovate-oblong, sub-fusiform; spire elevated, gradually tapering, and consisting of from eight to ten volutions; whorls nearly flat, or slightly convex, somewhat angulated above, and only nodulose in the region of the apex; surface covered with revolving raised lines, about five on each whorl below the upper angulation, above which they are less pronounced and more closely placed.

"Body-whorl convex, considerably longer than one-half the length of the shell, and ornamented by numerous raised lines, similar to those found on the other whorls. Toward the base these lines become more crowded, somewhat flexuous and coarse, appearing in the form of paired rugations; suture impressed; aperture elliptical, produced into a straight, but deflected, canal of considerable length.

"Columellar surface covered with a thick deposit of callus, which leaves partially uncovered a long and narrow umbilicus; columellar plaits three, the median one of which is the strongest.

"Length of longest specimen—imperfect below and above, and lacking probably an inch and a half—eleven inches; width across the centre, four inches.

"Caloosahatchie, in the banks below Fort Thompson." (Heilprin, 1887)

Holotype: WFIS 907.

Horizon: Unnamed upper Miocene formation; Caloosahatchee Formation, Pliocene. Florida.

Figured specimens: Fig. 3a, PRI 26912; height 120 mm, diameter 39 mm; locality TU 541. Fig. 3b, PRI 26913; height 40 mm, diameter 14 mm; locality TU 519. Other occurrences: TU locality nos. 79, 200, 202, 203, 283, 520, 523, 529, 532, 535, 539B, 540, 579, 583.

Discussion: This species is widespread in the late Neogene of southern Florida. It first appears in the uppermost Miocene where it is exceedingly common, particularly at one locality near Brighton, on the north side of Lake Okeechobee (TU locality 520). It is possible here to collect the shell by the hundreds, were one so disposed. The species also is not rare in most of the Pliocene Caloosahatchee localities, although nowhere as common as at Brighton. However, at the close of the Pliocene, *T. regina* disappeared from the Florida area. If *T. laevigata* is descended from the Venezuelan sequence as mentioned above, then the *T. regina* line leaves no descendants.

With the large number of specimens available the writer was able to make a study of the range of variation present in this species, with the hope that it might shed some light on other species of *Turbinella.* Fifty adult specimens from various localities in southern Florida were measured for length (approximated to what it should be if the specimen were complete) and diameter. From these measurements the following data were derived.

Average length of 50 specimens: 132 mm.
Average width of 50 specimens: 42 mm.
Length-width ratio of hypothetical "average" shell—3.1/1
Ratio for largest shell measured (length 310 mm)—3.1/1
Ratio for smallest shell measured (length 60 mm)—3.2/1

The range of figures calculated for the length-width ratios of 50 specimens is from 2.6 to 3.6 with 42 of the group falling between 2.8 and 3.3. The largest number fell in the 3.1 to 3.3 range with 33 being in that range.

It was also possible to measure the average diameter of the nuclear shell of both *T. regina* and *T. scolymoides* which often occurs with it. For *T. regina,* 25 specimens measured an average of 3.3 mm in diameter, ranging between 3.0 and 4.0 mm. For *T. scolymoides,* 30 specimens measured an average of 5.7 mm, with the range being 4.5 to 7.0 mm. Thus, it is immediately possible to distinguish the juvenile shells of these two

species solely on the basis of the nuclear diameter.

Turbinella laevigata Anton

Turbinella laevigata Anton, 1839, Verzeichniss der Conchylien, Halle, p. 71.
Turbinella ovoidea Kiener, 1841, Coquilles Vivantes, v. 6, p. 7, pl. 17, fig. 1.
Turbinella ovoidea Kiener. Reeve, 1847, Conchologia Iconica, v. 4, *Turbinella*, pl. 4, fig. 23.
Turbinella ovoidea Kiener. Heilprin, 1887, Wagner Free Inst. Sci., Trans., v. 1, p. 74.
Turbinella ovoidea Kiener. Dall, 1890, Wagner Free Inst. Sci., Trans., v. 3, pt. 1, p. 96.
Xancus ovoidea (Kiener). Maury, 1917, Bulls. Amer. Paleont., v. 5, no. 29, p. 84 (248); Maury, 1925, *ibid.*, v. 10, no. 42, p. 207 (359); Maury, 1925, Serv. Geol. Min. Brasil, Mon. 4, p. 152-153.
Turbinella ovoidea Kiener. Pilsbry, 1922, Acad. Nat. Sci. Phila., Proc., v. 73, p. 343 (also as *Xancus ovoideus*).
Turbinella ovoidea Kiener. Vredenburg, 1923, Geol. Surv. India, Records, v. 55, pt. 2, p. 120 *et seq.*
Xancus laevigatus (Anton). Winckworth, 1939, Malac. Soc. London, Proc., v. 23, p. 347.
Xancus laevigatus (Anton). M. Smith, 1940, Worldwide Seashells, p. 64, fig. 861.
Xancus laevigatus (Anton). Abbott, 1950, Johnsonia, v. 2, no. 28, p. 207, pl. 91, figs. 1, 2.
Xancus laevigatus (Anton). Ferreira and Cunha, 1957, Mus. Paraense Emílio Goeldi, Bol.; Geologia No. 4, p. 26.

Diagnosis: "Adult shell varying from 100 to 120 mm in length (4 to 5 inches). Solid and heavy, somewhat turnip-shaped. Whorls 7 to 8, globose, smooth. Color of shell dull white, but often hidden by the moderately thick, brown periostracum. Spire pointed but not high, slightly to moderately concave, with the whorls becoming increasingly more rounded. Suture fairly even, deeply indented. Aperture relatively small, elongate, narrowing posteriorly into a narrow channel and produced anteriorly into a relatively short siphonal canal. Parietal wall, in adults, developed into a small, glazed shield which, at the spire end, possesses a low, rounded, thick callus. Length of last whorl (aperture and siphonal canal) equal to or slightly more than ⅔ that of the entire shell. Outer lip heavy with a fairly sharp edge. Columella possesses on its center three well-developed plicae, the upper two being the largest. They protrude laterally and slightly downward from the columellar wall. Opposite these, and on the inside of the body whorl, there is a raised, spiral, irregular ridge in most specimens. Axial sculpture confined to the earlier whorls and consists of about 6 low, rounded, tubercules. Spiral sculpture consists of about 10 raised, even threads on the top third of each whorl and on the outside of the siphonal canal. Nuclear whorls unknown. Periostracum fairly thick, persistent, light to dark brown. Operculum corneous, heavy, unguiculate, dark brown, 2½ times as long as wide, narrow at each end, and with a very large muscle scar. Animal unknown." (Abbott, 1950)

Holotype: Lost.

Type Locality: Bahia, Brazil (selected by Abbott, 1950, p. 208).

Discussion: Although *T. laevigata* now apparently is restricted to one small area off the northeastern coast of Brazil, it is the only living representative of a group which once flourished from Florida to Venezuela.

T. laevigata has for years been known under a different name, that of *T. ovoidea*

Plate II

Figures Page

1. *Turbinella chipolana* Dall ---- 58
   a. USNM 111914 (Holotype); height 44 mm, diameter 18 mm (X 1½)
      Locality: USGS 2212. Chipola Formation.
   b. USNM 498892 ("cotype"); height 120 mm, diameter 55.5 mm (X 1)
      Locality: USGS 2212. Chipola Formation.
   c. PRI 26914; height 23 mm, diameter 9.5 mm (X 2)
      Locality: TU 546. Chipola Formation.

2. *Turbinella dalli* E. H. Vokes, n. sp. ---- 59
   a, b. PRI 26918 (Holotype); height 85 mm, diameter 41 mm (X 1)
      Locality: TU 554. Chipola Formation.
   c. PRI 26919 (Paratype); height 22 mm, diameter 11 mm (X 2)
      Locality: TU 547. Chipola Formation.

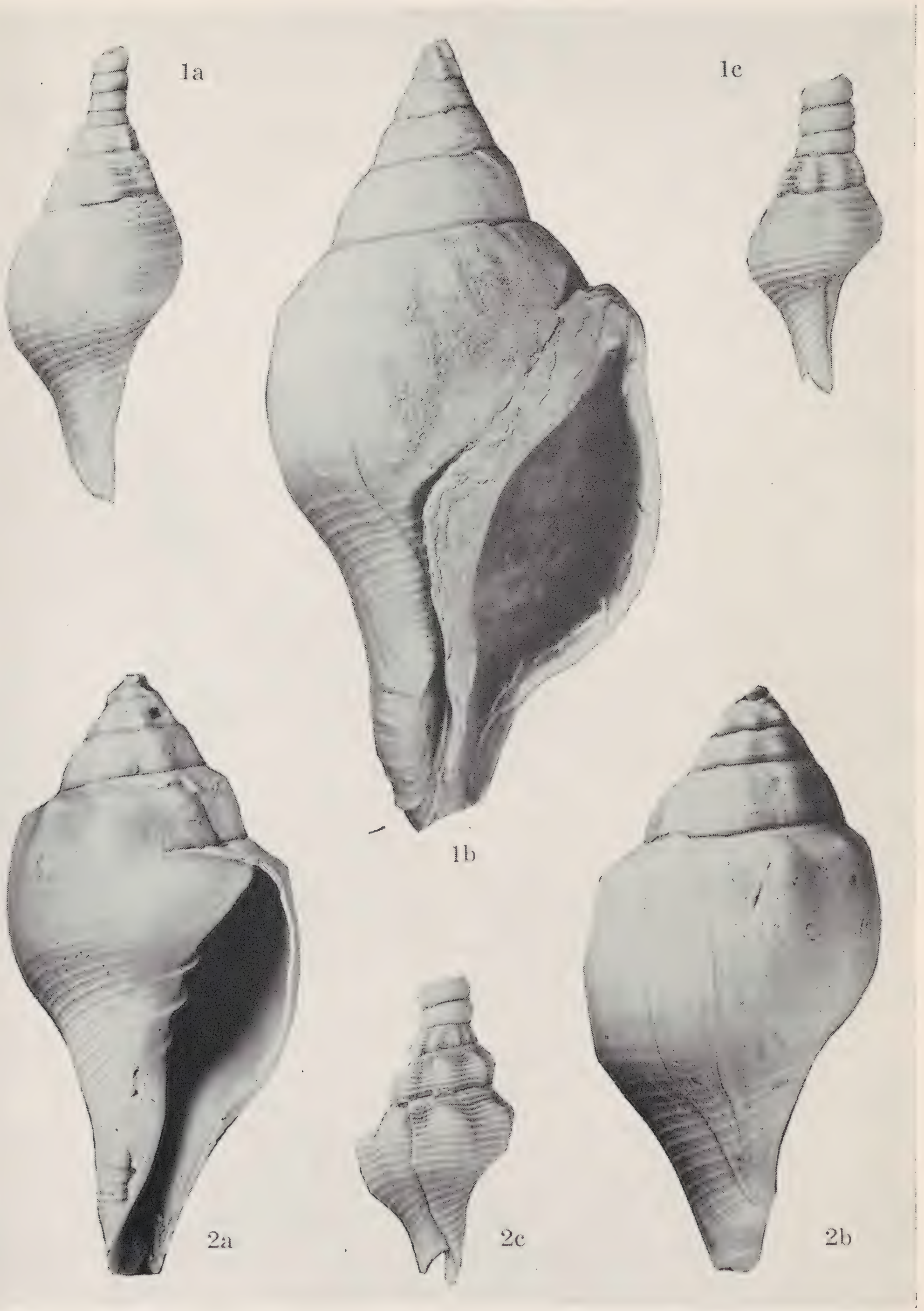

PLATE II

Kiener. However, Winckworth in 1939 (p. 347) made the statement, "Unfortunately it has an earlier name, *Turbinella laevigata* Anton 1839." Although Winckworth did not document his statement the change in nomenclature has been accepted by subsequent writers and therefore can no longer be dismissed as a *nomen oblitum.* Anton did not refer to any published figure, nor did he give a locality. His description, although it may very well be of *T. ovoidea,* could equally apply to the Indian species. Anton's types are no longer extant so that the actual species to which he referred cannot be determined.

THE "*ANGULATA*" LINEAGE

TURBINELLA CHIPOLANA Dall

Plate II, figures 1a, 1b, 1c

Turbinella chipolana DALL, 1890, Wagner Free Inst. Sci., Trans., v. 3, pt. 1, p. 97, pl. 10, fig. 7.

Turbinella chipolana Dall. MAURY, 1902, Bulls. Amer. Paleont., v. 3, no. 15, p. 60 (370).

Turbinella chipolana Dall. HUBBARD, 1921, N. Y. Acad. Sci., Sci. Surv. Porto Rico & Virgin Islands, v. 3, pt. 2, p. 153.

Turbinella chipolana Dall. VREDENBURG, 1923, Geol. Surv. India, Records, v. 55, pt. 2, p. 126.

Xancus chipolanus (Dall). GARDNER, 1944, U.S.G.S. Prof. Paper 142-G, p. 439, pl. 49, fig. 1, (after Dall).

Diagnosis: "This form would at first sight be taken for a variety of *T. wilsoni* with a little shorter spire and more rounded whorls than that species, but a study of a good series shows the following distinctive characters:

"The last whorl is rounded and not with flattened sides and the keel at the shoulder is obsolete; there is no presutural constriction or band; the whorls, except in the earliest on two [*sic*], are not appressed, but distinct or even partially channelled; the space of 20.0 mm from the base of the larval shell forward includes three and a half instead of seven whorls; instead of seven or more ribbed whorls there are but two or three; instead of uniform strong spiral threads as in *T. wilsoni,* the spirals on the early whorls alternate coarse and fine; the whorls are gracefully rounded and not flattened; the diameter of the spire at the anterior end of the larval shell is 4.0 mm, instead of 1.3 mm, the spirals are finer and continue more distinctly over the whorls in the adult; the adult shell has six whorls beside the nucleus, *T. wilsoni* has eleven or more in the same length." (Dall, 1890)

Dimensions of holotype: height 44 mm, diameter 18 mm.

Holotype: USNM 111914.

Horizon: Chipola Formation, uppermost lower Miocene. Florida.

Figured specimens: Fig. 1a, USNM 111914 (holotype); height 44 mm, diameter 18 mm; locality USGS 2212 (= TU 546). Fig. 1b, USNM 498892 ("cotype"); height 120 mm, diameter 55.5 mm; locality USGS 2212. Fig. 1c, PRI 26914; height 23 mm, diameter 9.5 mm; locality TU 546. Other occurrences: TU locality nos. 70, 453, 457, 547.

Discussion: There are three species of *Turbinella* in the Chipola Formation of northwestern Florida. The first described was *T. chipolana,* and because Dall figured only a juvenile specimen, more than a little confusion has resulted. Although the unfigured "cotype" of *T. chipolana* is 120 mm in height and appears to be an adult shell (see Pl. II, fig. 1b), two imperfect specimens have been found (TU loc. 453, 457) which indicate an ultimate height of at least 180 mm.

The affiliations of *T. chipolana* seem to lie with the *"angulata"* line, for it has the very large nucleus of that group. The neanic whorls lose their nodes at an early stage, between the second and third whorl, but the spiral ribbing continues much longer giving the shell a distinctive appearance. Not until almost the seventh post-nuclear whorl is the spiral ornamentation lost, and even then it persists on the pillar. The shoulder becomes obscurely noded in the adult shell and the outer lip flares up at the suture to form a thickened anal notch. The inner lip bears a heavy free-standing callus. The resemblance of *T. chipolana* to *T. dodonaia* has been discussed under that species and it was observed that the juvenile shells of the two species are readily separable. It is less easy, however, to distinguish the juvenile shells of *T. dalli,* n. sp., from those of *T. chipolana,* for the nuclei of both are approximately 4 mm in diameter. However, the young shell of *T. dalli* is much more strongly noded than *T. chipolana* and is more abruptly constricted into the pillar in the manner of the young of *T. scolymoides.* The adult shell of *T. dalli* has a much lower spire than *T. chipolana* and a relatively more inflated body whorl.

TURBINELLA DALLI E. H. Vokes, n. sp.
Plate II, figures 2a, 2b, 2c

Turbinella polygonata Heilprin. DALL, 1890, Wagner Free Inst. Sci., Trans., v. 3, pt. 1, p. 97 (in part).

Xancus polygonatus Heilprin. DALL, 1915, U. S. Natl. Mus. Bull. 90, p. 63 (in part).

Xancus sp. GARDNER, 1944, U.S.G.S. Prof. Paper 142-G, p. 440.

Diagnosis: Shell moderately large and heavy, body whorl inflated. Seven to eight post-nuclear whorls in the adult, plus three nuclear whorls. The nucleus consists of smooth, equi-diameter whorls which form a cylindrical protoconch, approximately 4 mm in diameter. The neanic whorls are strongly sculptured with about eight nodes. On the post-neanic whorls these nodes degenerate into tubercles at the shoulder, with about 12 of these ill-defined protuberances on the body whorl. Spiral ornamentation on the neanic whorls consists of approximately nine raised threads, which gradually die out, until the later whorls are very nearly smooth except on the pillar, where the sculpture consists of alternating strong and weak cords, perhaps a dozen of each. The pillar is broad, almost straight, with a slight anterior fasciole. Parietal wall lightly glazed with a callus wash, the columella bearing three plications of equal strength.

Dimensions of holotype: height 85 mm (lacking about 7 mm of nucleus and early neanic whorls); diameter 41 mm.

Holotype: PRI 26918; paratype: PRI 26919.

Type locality: TU 554, East bank of Chipola River, at power line crossing (SW ¼ Sec. 17, T1N, R9W), Calhoun County, Florida.

Horizon: Chipola Formation, uppermost lower Miocene. Florida.

Figured specimens: Fig. 2a, 2b, PRI 26918 (holotype); height 85 mm, diameter 41 mm; locality TU 554. Fig. 2c, PRI 26919 (paratype); height 22 mm, diameter 11 mm; locality TU 547.

Discussion: T. dalli is rare in the Chipola Formation, the few specimens found have been assigned to *T. polygonata.* Gardner discussed this species, stating: "There is another species at Alum Bluff, too imperfect to name but represented, possibly, by very young shells and by decorticated fragments of adults that must have attained a height of at least 200 millimeters. The fragments referred by Dall to the Tampa species, *Turbinella polygonata* Heilprin, are doubtless referable to this undescribed form." (1944, p. 440). Specimens from Alum Bluff are poorly preserved as the outgrop usually is below water. However, one good specimen of this species has been collected on the Chipola River. This specimen is not an adult but is sufficiently "mature" so that its selection as type is justified. The maximum size this species attains is not known, but Gardner suggested that the species reaches 200 mm (see above quote).

The juvenile shell of *T. dalli* may be distinguished from the similar shell of *T. chipolana,* with which it occurs, by the stronger nodes on the neanic whorls of *T. dalli,* and the more inflated appearance of the shell. The adult shell is distinguishable from both *T. chipolana* and *T. dodonaia* by its very much lower spire. In addition the neanic whorls are strongly noded to a later stage than is *T. chipolana.* These nodes gradually pass into tubercles at the shoulder of the adult whorl and are never completely lost. This new species is probably ancestral to the Pliocene form *T. scolymoides* as the juvenile shells are very similar.

Although referred to *T. polygonata* by Dall, the shells of *T. dalli* differ from that species not only in the early development but have a more sloping shoulder, a more inflated body whorl, and a much lower spire.

TURBINELLA BRASILIANA (Maury)

Xancus brasilianus MAURY, 1925, Ser. Geol. Min. Brasil, Mon. 4, p. 154-155, pl. 7, fig. 3.

Xancus brasilianus Maury, WOODRING, 1928, Carnegie Inst. Washington, Publ. 385, p. 252.

Xancus brasilianus Maury. FERREIRA and CUNHA, 1957, Mus. Paraense Emílio Goeldi, Bol.; Geologia No. 2, p. 35.

Diagnosis: "Shell with the early whorls very finely striated with threads alternating in thickness, and corrugated with rounded, irregularly undulating, longitudinal ribs. Later whorls not excavated posteriorly, but evenly rounded. Last whorl convex, not angulated as in the preceding species [*T. grata*]. Columella with three distinct folds, which appear on the mold as strong, deep transverse grooves. Length of shell 70 mm, width 24 mm. The specimen is probably a young shell." (Maury, 1925)

Holotype: DGM 570.

Horizon: Pirabas Limestone, uppermost lower Miocene. Pará, Brazil.

Discussion: This species is based on an immature specimen of a species of the *"angulata"* line. It is similar to the young of both *T. textilis* and *T. scolymoides,* but is sufficiently different from each to be con-

sidered as a distinct species. The Pirabas Limestone was correlated with the Chipola Formation by Maury (1925, p. 139); however, *T. brasiliana* is dissimilar to *T. chipolana* and *T. dalli,* n. sp., the *"angulata"* representatives in those beds, so the exact affiliations are uncertain.

Turbinella textilis (Guppy)

Fasciolaria textilis Guppy, 1873, Proc. Sci. Assoc. Trinidad, v. 2, p. 80 (*ex* Harris reprint: Bull's. Amer. Paleont., 1921, v. 8, no. 35, p. 64 (212).); Guppy, 1874, Geol. Mag. (decade 2) v. 1, p. 410, pl. 16, fig. 5; p. 438.

Turbinella textilis (Guppy). Dall, 1890, Wagner Free Inst. Sci., Trans., v. 3, pt. 1, p. 99; Dall, 1903, *ibid.*, pt. 6, p. 1583.

Xancus textilis jamaicensis Pilsbry, 1922, Acad. Nat. Sci. Phila., Proc., v. 73, p. 307, 343, pl. 25, figs. 5, 6.

Turbinella textilis (Guppy). Vredenburg, 1923, Geol. Surv. India, Records, v. 55, pt. 2, p. 126.

Xancus textilis (Guppy). Woodring, 1928, Carnegie Inst. Washington, Pub. 385, p. 250, pl. 15, fig. 3 (Holotype).

Xancus textilis jamaicensis "Pilsbry and Johnson." Ferreira and Cunha, 1957, Mus. Paraense Emílio Goeldi, Bol.; Geologia No. 2, p. 35.

Diagnosis: "Elongate, fusiform, closely cancellated by numerous spiral ridges from 1 to 2 mm distant between which are (especially anteriorly) one, two, or three finer threadlike ribs; and by numerous closer and smaller longitudinal lines. Whorls 6, the first two of which are smooth, the apex deciduous and usually wanting, the last more than two-thirds of the shell, rather ventricose above the middle, produced and rather attenuated anteriorly; bearing on the upper half 5-7 elongate rounded tubercular prominences. Columella margin with three strong tooth-like plaits. — Interior of peristome smooth. Length nearly 70 mm breadth 30." (Guppy, 1873)

Holotype: USNM 115482.

Horizon: Bowden Formation, middle Miocene. Jamaica.

Discussion: Originally assigned to the genus *Fasciolaria* by Guppy, this species was based on an immature specimen. The adult form later was named *Xancus textilis jamaicensis* by Pilsbry (1922). Pilsbry gave no reason for assigning the subspecific designation, and Woodring subsequently placed the two forms in synonymy. This species apparently is rare and Woodring (1928, p. 251) stated, "Not more than three specimens are in any collection." He also added that none of the specimens are mature except the holotype of *T. jamaicensis,* which shows that "on the later whorls of adult shells the axial and spiral sculpture is somewhat suppressed, and it also shows that the later whorls have an axially wrinkled concave area adjoining the suture." According to Woodring, "the most striking feature of this species is the very large nucleus," which suggests a close relationship with the Florida species *T. scolymoides* also characterized by an exceedingly large nucleus. *T. scolymoides* differs from *T. textilis* in lacking the pronounced sutural concavity of that species.

Turbinella magdalenensis (Weisbord)

Xancus magdalenensis Weisbord, 1929, Bulls. Amer. Paleont., v. 14, no. 54, p. 46 (278), pl. 7 (42), fig. 1.

Diagnosis: "Shell ponderous, solid and heavy; spire with 9 or 10 whorls when complete. Earlier whorls with about 6 wide rounded costae at about the middle. These costae later develop into [five] large protruding rather pointed knobs. The whorls are sculptured with fairly strong revolving lirae and intercalary finer threads. On the later whorls, transverse growth lines become numerous and give a reticulate pattern to them. Sutures narrow, well incised. Body whorl nearly smooth above, but ornamented below with alternating stronger and finer revolving lines, crossed by fine transverse growth striae. There are three strong columellar plaits, the anterior one slightly sulcate. Below this there is another weak fold. Umbilicus narrow and deep. Anterior canal long and narrow.

"Dimensions: Alt. (when whole) 190 mm; Approximate width 93 mm." (Weisbord, 1929)

Holotype: PRI 22956.

Horizon: Tuberá Group, middle Miocene. Dept. of Atlantico, Colombia.

Discussion: T. magdalenensis is strikingly similar to the Recent *T. angulata.* It differs primarily in having only five axial nodes on each whorl in contrast to the six nodes characteristic of *T. angulata.* In addition the nodes are developed at an earlier age, so that the overall aspect of the shell of *T. magdalenensis* is more nodose. The suture of *T. magdalenensis* is distinctly incised, while that of *T. angulata* is rather markedly appressed.

This species occurs in the Tuberá Group which is correlated with the Gatun Formation of Panama. *T. magdalenensis* is closely akin to another middle Miocene species, *T. scopula* Olsson, described from the Gatun

Formation of Costa Rica. The latter is an extremely coronate form which bears seven, high, rounded axial nodes.

TURBINELLA SCOPULA (Olsson)

Xancus scopulus OLSSON, 1922, Bulls. Amer. Paleont., v. 9, no. 39, p. 111 (283), pl. 11 (14), fig. 1.

Xancus scopulus Olsson. WOODRING, 1928, Carnegie Inst. Washington, Publ. 385, p. 252.

Xancus scopulus Olsson. WEISBORD, 1929, Bulls. Amer. Paleont., v. 14, no. 54, p. 47 (279).

Diagnosis: "Shell large, solid and heavy; spire nearly as long as the aperture; spire-whorls 6 plus (the tip broken), strongly coronate above and with large, wide, persistant ribs; the earlier spire-whorls are simply shouldered or angled about the middle, but the area about the upper sutures rapidly deepens and on the later whorls is a deep, excavated sutural zone, above which project the ends of the ribs; there is a strong sutural cord and a rather wide, ribbon-like band just above, forming at first a strongly appressed suture; the last whorl has about 7 large, wide ribs, the areas between appearing as troughs or depressions; the sutural excavated zone carries several irregular spiral threads which are crossed by large growth-lines so that the resulting sculpture is more or less cancellate, more particularly on the earlier whorls; the growth-lines cross the sutural cord and upon the ribbon above, become much crowded and strongly bent forwards; the young shell was sculptured over the whole shell with strong spirals, but with maturity, the spirals become obsolete and the shell is smooth and polished; columella with 3, strong plicae as in the recent *scolymus;* a long anterior canal, with a narrow, deep umbilicus behind the spreading inner lip.

"Height 265, diameter 136, aperture 158, last whorl 195 mm." (Olsson, 1922)

Holotype: PRI 21071.

Horizon: Gatun Formation, middle Miocene. Costa Rica.

Discussion: T. scopula represents an extreme development of the *"angulata"* stock in which the axial nodes are very high and projecting. The shoulder is wide and deeply excavated with the tops of the nodes level with the suture. *T. magdalenensis* from the middle Miocene of Colombia is much like this species and may represent only a local variant. Both are very close to the Recent *T. angulata,* closer in fact than the Pliocene species, *T. scolymoides,* which is presumed to be immediately ancestral to *T. angulata.*

TURBINELLA SCOLYMOIDES Dall

Plate III, figures 1a, 1b

Turbinella scolymoides DALL, 1890, Wagner Free Inst. Sci., Trans., v. 3, pt. 1, p. 98, pl. 3, figs. 2, 5; DALL, 1892, *ibid.,* pt. 2, p. 229.

Turbinella scolymoides Dall. PILSBRY, 1922, Acad. Nat. Sci. Phila., Proc., v. 73, p. 343.

Turbinella scolymoides Dall. VREDENBURG, 1923, Geol. Surv. India, Records, v. 55, pt. 2, p. 127.

Xancus scolymoides (Dall). DUBAR, 1958, Florida Geol. Surv., Bull. 40, p. 190.

Diagnosis: "Shell much resembling the recent *T. scolymus* L., especially when young, but having a more elongated and acute spire and canal, with two more whorls to the same diameter in the young shell; it is more globose, smooth and less ribbed on the body-whorl and with a proportionally shorter canal in the adult. Whorls ten or eleven without the nucleus, from which the protoconch has in all the specimens been lost during the life of the animal.

"The larval shell without the protoconch appears to have had not to exceed one short whorl with incremental striae, but it is, in the absence of a complete specimen, unsafe to form a conclusive opinion on the point. The minute sculpture of the young is exactly like that of *T. scolymus,* but in the adult the fine sculpture and ribbing are obsolete and the body-whorl is inflated and nearly smooth. The pillar is straight, short, with a deep umbilical foramen, the whole shell is thin and light, considering its size. The suture is distinct and lies on a thin band of callus, in the last whorl, which extends a little behind the suture. The adult figured is 231 x 140 mm, but when perfect was about 260 mm in length." (Dall, 1890)

Holotype: USNM 111924.

Horizon: Caloosahatchee Formation, Pliocene; unnamed post-Caloosahatchee formation, Pleistocene. Florida.

Figured specimens: Fig. 1a, PRI 26915; height 108 mm, diameter 45 mm; locality TU 202. Fig. 1b, PRI 26916; height 32 mm, diameter 14 mm; locality TU 580. Other occurrences: TU locality nos. 79, 201, 519, 527, 529, 532, 536, 539B, 541, 579, 583, 584.

Discussion: While generally occurring in the same beds as *T. regina* Heilprin, *T. scolymoides* is the less common species. It is not certain that *T. scolymoides* ranges into the uppermost Miocene, for the boundary between these beds and the Pliocene Caloosahatchee Formation is almost impossible to ascertain. There are a number of localities that are believed to be Miocene in which only *T. regina* occurs (*e.g.,* TU localities 283, 520, 535), however there are also other localities which also may be Miocene in

which both species are found. More stratigraphic work must be done before the absolute range of *T. scolymoides* is established.

It is equally difficult to determine the upper limit, for it is possible that the *scolymoides* form still lives today. Abbott (1950, pl. 90, fig. 3) figured a Recent specimen of *T. angulata* which is exceedingly close to *T. scolymoides* and he said (p. 204): "The spiral threads on the whorls are prominent in some shells [of *T. angulata*]." The writer has collected Recent specimens off the coast of Campeche, Mexico, which seem identical with *T. scolymoides.* This form occurs with the true *T. angulata* and probably is, as Abbott treated it, only a variant of *T. angulata;* however, it may be a different species, the descendant of the Pliocene *T. scolymoides. T. scolymoides* certainly survived to the Pleistocene (TU localities 201, 580) in southern Florida and there is no reason to believe that it is now extinct. The typical smooth *T. angulata* resembles more closely the middle Miocene species, *T. magdalenensis* and *T. scopula,* than it does the Pliocene *T. scolymoides.* It gives cause to wonder whether the ancestry of *T. angulata* is not more directly linked to these South and Central American species than to the Florida one. *T. angulata* and *T. scolymoides* occur together at one Florida Pliocene locality (TU 519) and it may be that this marks an invasion by the new species from a more southern point of origin rather than the appearance of a new "mutation."

The embryonic shell of *T. scolymoides* is strikingly large and a juvenile specimen may be distinguished from a comparable shell of *T. regina* at a glance, as discussed under that species. Although the type specimen is a large shell, most specimens collected are smaller. A length of 200 mm is rare, the usual size being about 100 mm. However, one specimen in the collection of the Paleontological Research Institution measures almost 400 mm. Because of the preponderance of smaller specimens it has been said to be distinguished from *T. regina* by its smaller size. This is not entirely accurate, but is a good generalization. A far greater number of specimens of *T. regina* attain a larger size.

Turbinella angulata (Solander *in* Lightfoot)

Plate III, figures 2a, 2b

Voluta angulata Solander *in* Lightfoot, 1786, Portland Catalogue, p. 76.
Murex scolymus Gmelin, 1791, Systema Naturae, ed. 13, v. 1, pt. 6, p. 3553.
Turbinella scolymus (Gmelin). Lamarck, 1816, Tableau Encyclop. et Méth., pl. 431b, figs. 2a, 2b.
Turbinella scolyma (Gmelin). Reeve, 1847,

Plate III

Figures — Page

1. *Turbinella scolymoides* Dall ---- 61
   a. PRI 26915; height 108 mm, diameter 45 mm (X 1)
   Locality: TU 202. Caloosahatchee Formation.
   b. PRI 26916; height 32 mm, diameter 14 mm (X 2)
   Locality: TU 580. Unnamed post-Caloosahatchee Formation.

2. *Turbinella angulata* (Solander *in* Lightfoot) ---- 62
   a. PRI 26917; height 107.5 mm, diameter 46.5 mm (X 1)
   Locality: TU 519. Caloosahatchee Formation.
   b. PRI 26917a; height 32 mm, diameter 15 mm (X 2)
   Locality: TU 519. Caloosahatchee Formation.

3. *Turbinella regina* Heilprin ---- 55
   a. PRI 26912; height 120 mm, diameter 39 mm (X 1)
   Locality: TU 541. Unnamed upper Miocene formation.
   b. PRI 26913; height 40 mm, diameter 14 mm (X 2)
   Locality: TU 519. Caloosahatchee Formation

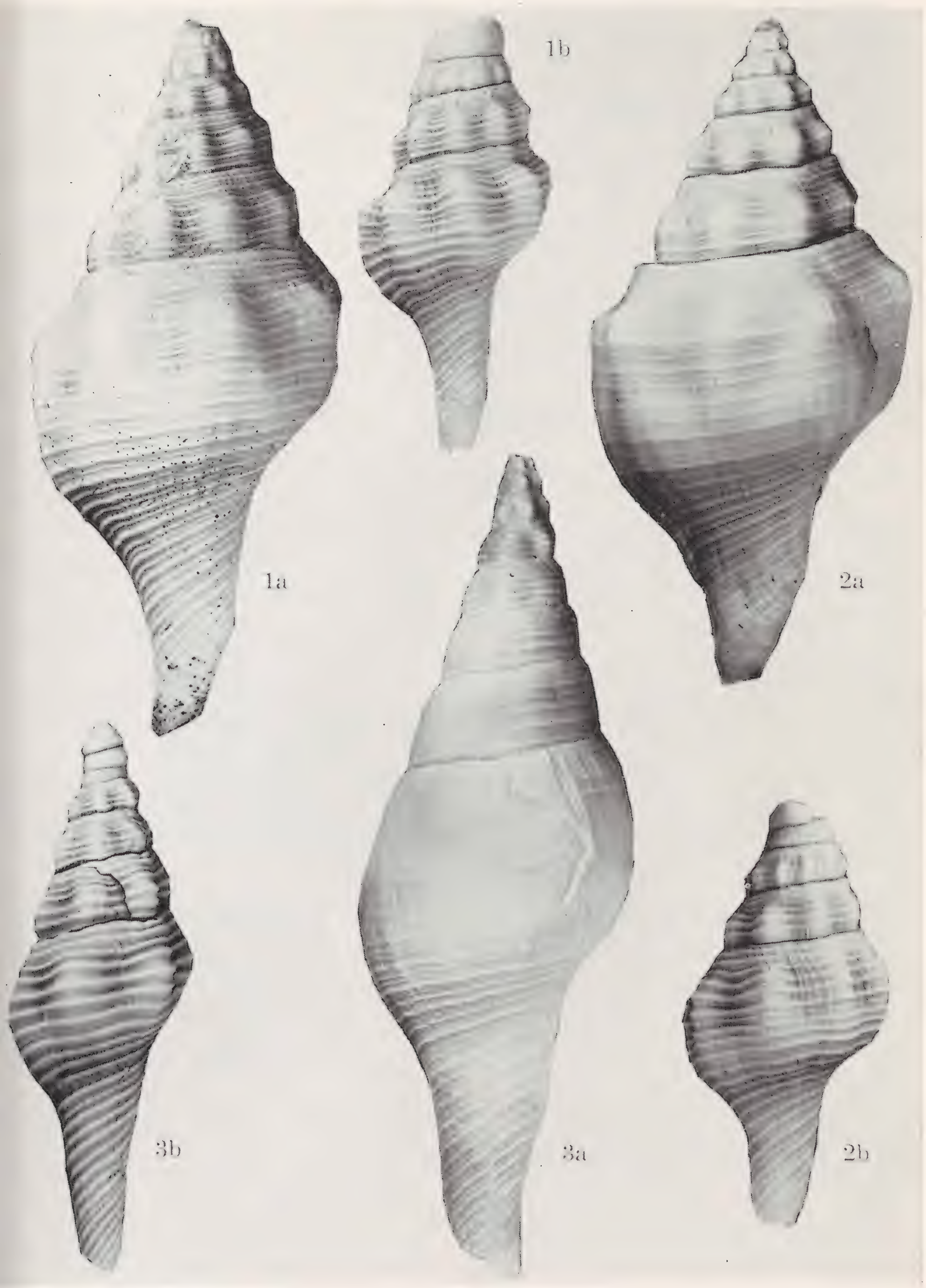

PLATE III

Conchologia Iconica, v. 4, *Turbinella*, pl. 1, fig. 4.

Turbinella scolymus (Gmelin). HEILPRIN, 1887, Wagner Free Inst. Sci., Trans., v. 1, p. 74.

Turbinella scolymus (Gmelin). DALL, 1890, Wagner Free Inst. Sci., Trans., v. 3, pt. 1, p. 96.

Xancus scolymus (Gmelin). PILSBRY and JOHNSON, 1917, Acad. Nat. Sci. Phila., Proc., v. 69, p. 167.

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Xancus scolymus (Gmelin). WEISBORD, 1929, Bulls. Amer. Paleont., v. 14, no. 54, p. 47 (279).

Xancus angulatus (Solander). M. SMITH, 1940, Worldwide Seashells, p. 64, fig. 859.

Xancus angulatus (Solander). ABBOTT, 1950, Johnsonia, v. 2, no. 28, p. 204, pl. 90, figs. 1-3.

Xancus angulatus (Solander). ABBOTT, 1955, American Seashells, p. 244.

Diagnosis: "Adult shell varying from 180 to 360 mm in length (7 to 14 inches). Solid, heavy, and fusiform in shape. Whorls 8 to 11, angulate at the shoulder and with prominent blunt tubercles at the top of the whorl. Color of shell cream-white, but often hidden by the thick, light-brown periostracum. Spire pointed, flat-sided, and of an angle of 50 to 60 degrees. Suture prominent, wavy, well-indented. Aperture large, elongate, with a porcelaneous finish and colored either a yellowish-white, pinkish-cream or a deep, brownish-orange. Parietal wall in adults developed into a thick, oval shield which has a glossy finish and is often more richly colored than the aperture. The shield continues anteriorly into the long, open siphonal canal. The length of the last whorl (aperture and siphonal canal) is generally ⅔ of the length of the entire shell. Outer lip strong, sharp, and often slightly crenulated at the edge on the lower third. Columella bears 3 strong, widely-spaced, rounded plicae or plaits which run back into the shell. They are situated opposite the widest part of the aperture and appear to be almost on a plane vertical to the axis of the shell. There is a thickened, spiral, indistinct, and sometimes absent, ridge on the center of the body whorl inside the aperture. This often accompanies a spiral, light color-streak on the outside of the shell. Umbilicus irregularly formed, deep, slit-like. Axial sculpture consists of 6 to 8 prominent, blunt tubercles on the top of each whorl. Spiral sculpture consists of numerous, small, raised threads which are coarsely beaded by the interruption of the fine axial threads. These spiral threads are usually absent on the center of the body whorl. Nucleus large, bulbous and rather smooth. Periostracum thick, persistent, light-brown in color. Operculum horny, hard, unguiculate, dark-brown, 2½ times long as wide, narrow at each end, and with a very large muscle scar. Animal unknown." (Abbott, 1950)

Holotype: Lost. "Type figure": Martini, 1780, Conchyl.-Cab. (1), v. 4, fig. 1325 (selected by Abbott, 1950, p. 205).

Type locality: "Island of Providence" (Lightfoot, 1786, p. 16); Nassau, New Providence Island, Bahamas (Abbott, *ibid.*, p. 206).

Figured specimens: Fig. 2a, PRI 26917; height 107.5 mm, diameter 46.5 mm; locality TU 519. Fig. 2b, PRI 26917a; height 32 mm, diameter 15 mm; locality TU 519.

Discussion: This common Caribbean species appears in most of the literature as *Turbinella scolymus* (Gmelin). However *Voluta angulata* of the Portland Catalogue (1786) was based on the same figure as Gmelin's *Murex scolymus* and the older name has begun to become recognized. The Portland Catalogue was published anonymously, however, Dance (1962) proved the author to be Dr. John Lightfoot.

Turbinella angulata is a shallow water species, reported from intertidal flats by Abbott (1950, p. 202), and dredged from 14 to 20 fathoms (Springer and Bullis, 1956). It ranges from the Bahamas to Colombia. Large specimens may attain a length of almost 400 mm, although the average size is about 200 mm.

V. LOCALITY DATA

70. Chipola Fm., Ten Mile Creek, at bridge of Florida Highway 73 (NW¼ Sec. 12, T1N, R10W), Calhoun Co., Florida.
79. Caloosahatchee Fm., Ortona Locks, Caloosahatchee River, Glades Co., Florida.
91. Oak Grove Sand, type locality, west bank of Yellow River, about 100 yards below bridge at Oak Grove, Okaloosa Co., Florida.
200. Unnamed Miocene formation, marl pits south of Acline, Charlotte Co., Florida.
201. Unnamed post-Caloosahatchee formation, spoil banks, two miles south of Belle Glade, Palm Beach Co., Florida.
202. Caloosahatchee Fm., south bank of Caloosahatchee River, about two miles west of La Belle, Hendry Co., Florida.
203. Caloosahatchee Fm., north bank of Caloosahatchee River, about two miles east of Fort Denaud, Hendry Co., Florida.

283. Unnamed Miocene formation, 1.3 miles south of Murdock on Florida Highway 771, Charlotte Co., Florida.
334. Byram Marl, east side of U. S. Highway 61, about 1½ miles north of Vicksburg Natl. Military Cemetery, Vicksburg, Mississippi.
453. Chipola Fm., Alum Bluff, Apalachicola River (SE¼ Sec. 24, T1N, R8W), Liberty Co., Florida.
457. Chipola Fm., west bank of Chipola River (SW¼ Sec. 17, T1N, R9W), Calhoun Co., Florida. (Same as USGS 2213, "One mile below Bailey's Ferry.")
458. Chipola Fm., east bank of Chipola River, above Farley Creek, (Center Sec. 20, T1N, R9W), Calhoun Co., Florida.
459. Chipola Fm., east bank of Chipola River (NW¼ Sec. 29, T1N, R9W), Calhoun County, Florida.
519. Caloosahatchee Fm., Harney Pond Canal spoil banks, northwest side of Lake Okeechobee, Glades Co., Florida.
520. Unnamed Miocene formation, spoil banks, canal ⅓ mile east of Brighton, Highlands Co., Florida.
523. Caloosahatchee Fm., Harney Pond Canal spoil banks, six miles north of Florida Highway 78, Brighton Indian Reservation, Glades Co., Florida.
527. Caloosahatchee Fm., Pumping station 127, north shore Lake Okeechobee, Glades Co., Florida.
529. Caloosahatchee Fm., north bank of Caloosahatchee River, about three miles west of La Belle, Hendry Co., Florida.
532. ? Caloosahatchee Fm., spoil banks, canal (Center Sec. 24, T40S, R22E) southeast of Murdock, Charlotte Co., Florida.
535. Unnamed Miocene formation, Indian Prairie Canal spoil banks, at crossing of Florida Highway 78, Glades Co., Florida.
536. Caloosahatchee Fm., south bank of Caloosahatchee River, about one mile upstream from La Belle, Hendry Co., Florida.
539B. Caloosahatchee Fm., Shell Creek (Dall's locality), lower beds. About eight miles east of Cleveland, Charlotte Co., Florida.
540. Caloosahatchee Fm., Miami Canal spoil banks, one to three miles south of pumping station at Palm Beach county line, Broward Co., Florida.
541. Caloosahatchee Fm., spoil banks, Miami Canal, two miles north of pumping station at Broward county line, Palm Beach Co., Florida.
546. Chipola Fm., Ten Mile Creek, about 1 mile west of Chipola River (NE¼ Sec. 12, T1N, R10W), Calhoun Co., Florida.
547. Chipola Fm., west bank of Chipola River (SW¼ Sec. 29, T1N, R9W), Calhoun Co., Florida.
548. Chipola Fm., west bank of Chipola River (NW¼ Sec. 29, TIN, R9W), Calhoun Co., Florida.
549. Chipola Fm., east bank of Chipola River, about ½ mile below Four Mile Creek (NE¼ Sec. 32, T1N, R9W), Calhoun Co., Florida.
554. Chipola Fm., east bank of Chipola River, at power line crossing (SW¼ Sec. 17, T1N, R9W), Calhoun Co., Florida.
579. Caloosahatchee Fm., Miami Canal spoil banks, four miles north of pumping station at Broward County line, Palm Beach Co., Florida.
580. Unnamed post-Caloosahatchee formation, spoil banks, North New River Canal, one mile south of South Bay, Palm Beach Co., Florida.
583. Caloosahatchee Fm., Miami Canal spoil banks, seven miles north of pumping station at Broward County line, Palm Beach Co., Florida.
584. Unnamed post-Caloosahatchee formation, spoil banks, St. Lucie Canal, at Port Mayaca, Martin Co., Florida.
USGS 2212. Chipola Fm., Ten Mile Creek, one mile west of "Bailey's Ferry" on the Chipola River, Calhoun Co., Florida. (= TU 546)

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VII. APPENDIX I

Nomenclatorial note on the name *Turbinella* Lamarck

The name *Turbinella* Lamarck, 1799, was for many years considered the proper taxon for the genus typified by *Voluta pyrum* Linnaeus. However, there is an older name, *Xancus* Röding, 1798, based on the same species. This older name appears in the *Museum Boltenianum,* an account of the arrangement of the "cabinet" of shells of J. F. Bolten, of Hamburg. This system was published posthumously by his family with the assistance of a friend, Peter Friedrich Röding, who supplied references to the Gmelin edition of the *Systema Naturae* of Linnaeus and also to figures in the various iconographies, especially the *Conchylien-Cabinet* of Martini and Chemnitz. This publication, although exceedingly well done for its time, was relatively obscure until the beginning of this century. It was not, however, completely unknown to conchologists, for Mörch and H. & A. Adams cited "Bolten" names, but the influence of the Lamarck followers was such that, in general, the work was ignored. As nomenclature became increasingly sophisticated, a need for rules of priority became necessary. With the recognition that the taxa in the *Museum Boltenianum* were indeed the first binomial names applied to the species cited, the importance of this work could no longer be ignored by systematists. Therefore in 1906 a facsimile reprint was published by Sherborn and Sykes, and, reluctantly, the names of both genera and species cited therein began to replace the better known later ones. Dall was a particular advocate of the Röding names, in 1906 having given a review of the generic names of "Bolten" and assigned type species to the genera not already provided with same. In 1915 he further provided an Index to the "multitude of names contained in this small volume" in order to provide systematic workers in Mollusca "with some easy and feasible method of detecting them."

In the ensuing years there was much verbal sharpshooting by foes of the Röding names. In the case of *Xancus-Turbinella,* for example, Vredenburg (1923, p. 119) expressed a typical sentiment of the time, stating: "Commonsense refuses to submit to such an absurdity as *Xancus* Bolten. I cannot accept any of the Bolten nomenclature, the adoption of which would reflect discredit on the genius of Lamarck." Pilsbry, one of the staunchest anti-Boltenists proclaimed: "The replacement of the name *Turbinella* by *Xancus* is one of the outrages against scientific nomenclature consequent upon the adoption of Bolten's *Museum* as a source of generic and specific names." (1922, p. 342).

Many zoologists simply refused to accept the names, declaring that the work was only a "sales catalogue" and as such was not a "publication" under the International Rules of Zoological Nomenclature. The question

of the status of the *Museum Boltenianum* was finally placed before the International Commission on Zoological Nomenclature and in Opinion 96 (1926, p. 16-18) that body observed that the work "bears all the earmarks of a carefully prepared manuscript intended to be printed as a permanent record with only incidental reference to sale," and ruled that it was "nomenclatorially available under the International Rules."

The opponents of the *Museum Boltenianum* may have been down, but they were not out. One in particular, Joshua L. Baily, Jr., ultimately applied to the Commission to use its Plenary Powers to reject the name *Xancus* and reestablish *Turbinella.* Why Baily should have been concerned in the least with this special taxonomic controversy is somewhat of a mystery to this writer, as Baily lists himself as a specialist in the field of fresh-water Mollusca of the western United States (Blackwelder, 1961). His petition appeared in the Bulletin of Zoological Nomenclature (1956) and comments upon its worth were solicited by the Commission. In reply the Commission received comments (see Opinion 489, 1957) approving the action from four persons: a specialist in fish, a botanist, a specialist in land snails, and finally one from a marine conchologist. In addition there was one letter of support from the Royal Anthropological Institute of Great Britain and Ireland stating that the name *Turbinella* was preferred by that group. Objections were received from seven persons: among them R. Tucker Abbott, Myra Keen, and Harold A. Rehder, probably the three leading marine malacologists in the United States. One letter of opposition from A. N. Dusenbury, a paleontologist in Venezuela, was received too late for consideration. These letters of opposition carefully documented the usage of *Xancus* and *Turbinella* in the recent literature. Abbott stated that, "Of twelve popular identification books on mollusks published in the last fifteen years, eleven use *Xancus,* one used *Turbinella.* The scientific literature is almost unanimous in its use of *Xancus.* . . . A perusal of the Zoological Record shows that the vast majority of workers in the last fifteen years have been using *Xancus.*" Keen adds: "The name *Xancus* has almost without exception been adopted in scientific literature and by museums since 1927." Dusenbury had the most cogent point to make, however, saying that had the proposal been made in 1926 when the *Museum Boltenianum* was declared available there would have been no objections, but "in the thirty years which have elapsed since 1926, *Xancus* [Röding] and the family XANCIDAE are names which have become deeply rooted in paleontological and conchological literature. . . . Dr. Baily's proposal would penalize those authors who have followed the *Règles* and favor those who have neglected them."

In spite of the strong support given to the continuation of the usage of the name *Xancus,* the Commission voted 18 for suppression, and six against (Opinion 489, 1957). Presumably the non-zoological support from the anthropologists was a contributing factor in their decision, but the resulting confusion has not excluded the field of anthropology. Recently the writer (1963) published a paper on *Turbinella* in an anthropological journal, and was soon rebuked by a leading anthropologist for "using an obsolete name."

Whatever our personal preferences may be in this matter, we have little choice but to follow the decision of the Commission. However, Keen expressed the opinion of many when she warned, in her letter of protest over *Turbinella,* "I feel that granting this petition by the Commission would only add to the growing feeling among many systematists that the supposedly firm ground of priority is being made into a quagmire and that the number of exceptions to the *Règles* waxes too great to be worth trying to remember."

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April 30, 1964

ERRATA

VOLUME 1 (1962-1963)

NO. 1—page i, Editorial Committee. For H. V. Anderson, read H. V. Andersen.

page 66 from the plate descriptions was inadvertently omitted by the printer. A replacement leaf is available on request.

NO. 3—page 100, col. 1, line 33. The locality should read NE¼, not NW¼.

page 109, col. 1, lines 28-30. The quotation should read "the Florida specimens are often of a deep rose-pink."

page 112, locality 456. The locality should read NE¼, not NW¼.

page 112, locality 546. The locality should read about 1 mile west, not 1½ miles west; and (= USGS 2212), not (? same as USGS 2212).

page 113, locality 554. The locality should read SW¼ Sec. 17, not NW¼ Sec. 20.

NO. 4—plate 2, opposite page 130. The proper scale is: one mile = 3 inches.

page 154, col. 2, lines 36 and 38; also page 155, col. 1, line 4. For *Torvomurex,* read *Torvamurex.*

page 157, col. 2, line 25. For *consulae,* read *consuelae.*

TULANE STUDIES IN GEOLOGY

VOL. 1, NO. 1, ARKADELPHIA FORAMINIFERIDA, by Hubert C. Skinner, pp. 1-72 (August 31, 1962) 2.75

VOL. 1, NO. 2, STUDIES ON TERTIARY AND RECENT GIANT LIMIDAE, by Harold E. Vokes, pp. 73-92, and NO. 3, CENOZOIC MURICIDAE OF THE WESTERN ATLANTIC REGION, PART I—MUREX S.S., by Emily H. Vokes, pp. 93-123 (January 18, 1963)—BOUND TOGETHER $2.25

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TULANE STUDIES IN GEOLOGY

Volume 2, Number 3 June 30, 1964

THE SPECIES AND STRATIGRAPHIC DISTRIBUTION OF *CAUCASINA* AND *AEOLOMORPHELLA*, NEW GENUS (FORAMINIFERIDA)

ALFRED R. LOEBLICH, JR. and HELEN TAPPAN
CALIFORNIA RESEARCH CORP., LA HABRA, CALIFORNIA
AND UNIVERSITY OF CALIFORNIA, LOS ANGELES p. 69

COSTELLACESTA, A NEW SUBGENUS OF *LIMA* FROM THE CRETACEOUS OF THE GULF AND ATLANTIC COAST PROVINCE

ERLE G. KAUFFMAN
DEPARTMENT OF PALEOBIOLOGY
UNITED STATES NATIONAL MUSEUM p. 89

THE STATUS OF *DEIROCHELYS FLORIDANA* HAY WITH COMMENTS ON THE FOSSIL HISTORY OF THE GENUS

C. G. JACKSON, JR.
BIOLOGY DEPARTMENT
UNIVERSITY OF FLORIDA p. 103

PRINCIPLES OF PALEOECOLOGY: A REVIEW

HUBERT C. SKINNER
TULANE UNIVERSITY p. 107

TULANE UNIVERSITY OF LOUISIANA
New Orleans

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CALIFORNIA RESEARCH CORP., LA HABRA, CALIFORNIA AND UNIVERSITY OF CALIFORNIA, LOS ANGELES

CONTENTS

Page

I. Abstract 69
II. Introduction 70
III. Known Geologic and Geographic Distribution 70
IV. Ecologic Relationships 72
V. Familial and Phylogenetic Relationships 73
VI. Acknowledgments 74
VII. Systematic Descriptions 74
A. *Caucasina* 74
1. Upper Cretaceous Species 75
2. Paleocene Species 75
3. Eocene Species 75
4. Oligocene Species 78
5. Oligo-Miocene Species 78
6. Miocene Species 82
7. *Nomina Nuda* 83
8. *Nomenclatura Aperta* 84
B. *Aeolomorphella* 84
VIII. References 85
Plate 1 77
Plate 2 81

I. Abstract

Species of *Caucasina* are described and figured. Two Austrian Miocene species, *Bulimina elongata* and *B. subulata,* are transferred to *Caucasina* and new Californian species erected: *C. minuta* (Paleocene, Dos Palos Shale) and *C. khalilovi* (Oligocene, Rincon Formation). *Aeolomorphella,* new genus, is based on the new species, *A. plectilis* (north Alaskan Upper Cretaceous). *Caucasina* ranges from Upper Cretaceous (Campanian) to Miocene, occurring in both Old and New Worlds. Paleoecologic implications, as well as familial and phylogenetic relationships of the Caucasininae also are discussed.

Editorial Committee for this Paper:

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II. Introduction

The genus *Caucasina* was defined by Khalilov in 1951, and since has been widely reported in the Soviet Union from strata of Oligocene and Miocene age. The monotypic Cretaceous genus *Aeolostreptis* Loeblich and Tappan (1957) was described from the American Upper Cretaceous, but later regarded by us as a junior synonym of *Caucasina,* thus extending the geographic and geologic range to include the Upper Cretaceous of the American Gulf Coast (Loeblich and Tappan, 1961, p. 314). Eocene and Oligocene species of *Caucasina* were described by Khalilov (1958), and a new species was referred to the genus from the Eocene of France in 1961. The genus also has been reported from Yugoslavia by Sikić (1962).

Because of the distinctive morphological characters of the genus, the very limited records of its occurrence are somewhat surprising. The present compilation of previously described species is accompanied by the description of two new Californian species (of Paleocene and Oligocene age, respectively) and transfer to the genus *Caucasina* of two previously described species from the Austrian Miocene.

Because the species recorded to date have proved to be of considerable stratigraphic value, the present summary of the generic occurrence may aid in the recognition of these and additional species, in strata of other areas, and thus further increase their usefulness.

III. Known Geologic and Geographic Distribution

The earliest reported occurrence of *Caucasina* is in the Campanian, by which time the genus was present in both North America and Eurasia (fig. 1). *Caucasina tuzkoensis* was described from the Campanian of the region of the Amu Darya River and Bukhara, in Uzbek SSR, and the Kyzyl Kum of Uzbek and Kazakh SSR, central Asia (Suleymanov, 1962), and *Caucasina vitrea* (Cushman and Parker) occurs in the Selma Chalk of nearly equivalent age in Mississippi. Of nearly the same age, and perhaps derived from *Caucasina,* is the north Alaskan form *Aeolomorphella plectilis,* new species.

No Maastrichtian records are known as yet (fig. 2), but a new Danian (Paleocene) species is here described from the Dos Palos Shale of California. Another gap in the known record represents the Landenian (upper Paleocene) and lower and middle Eocene (Ypresian, Lutetian), although the *nomen nudum C. "suzakensis"* is reported from the Paleocene (Pg_1) of Fergana, central Asia (Bykova, 1960). Two species have been recorded from the upper Eocene of Azerbaijan SSR: *C. eocaenica* from the Lesser Caucasus, east Azerbaijan and the Azov Kuban basin (Khalilov, 1958; Nikitina, 1962), and *C. aziderensis* from the upper Eocene-Oligocene of

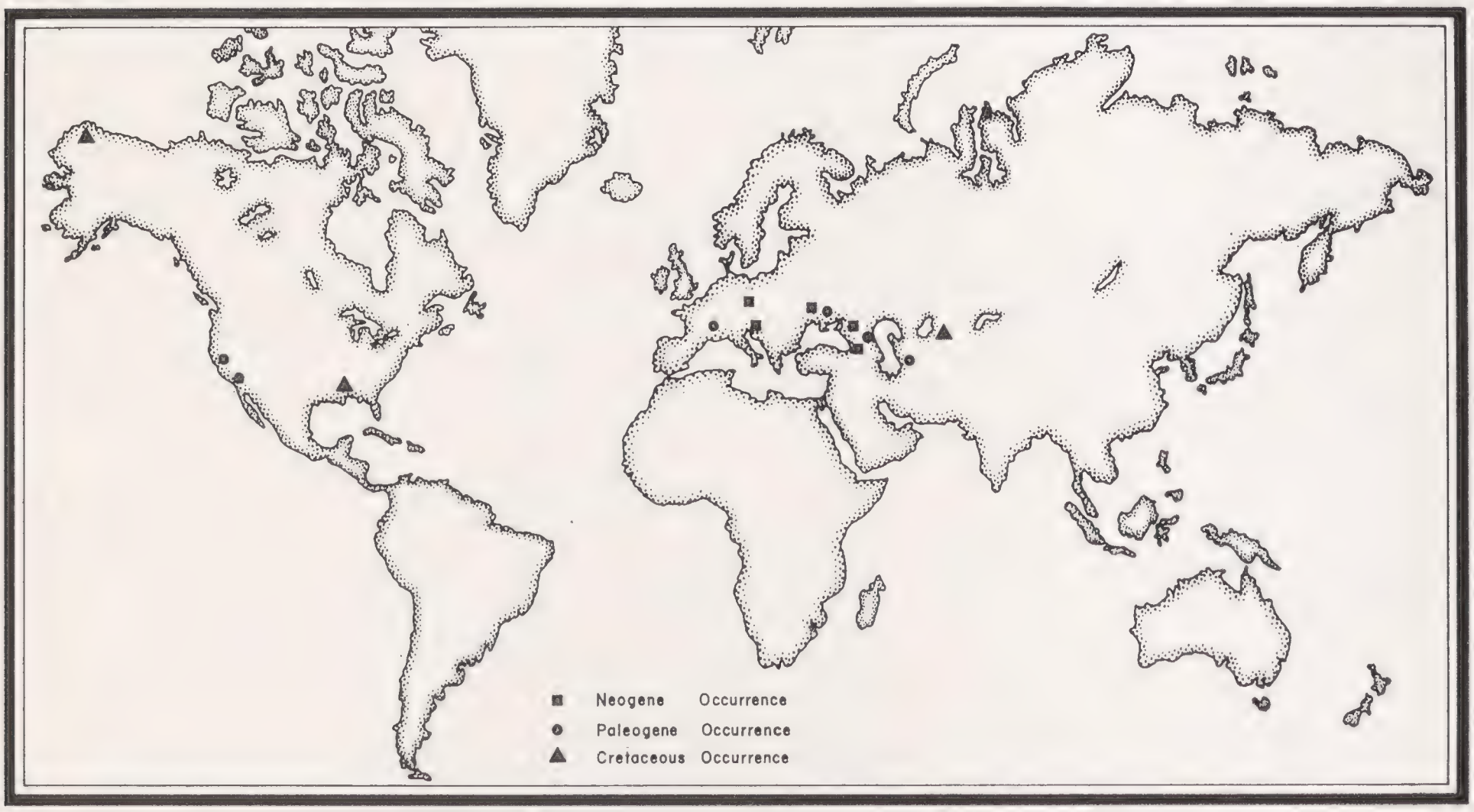

Figure 1. Occurrence of Caucasininae.

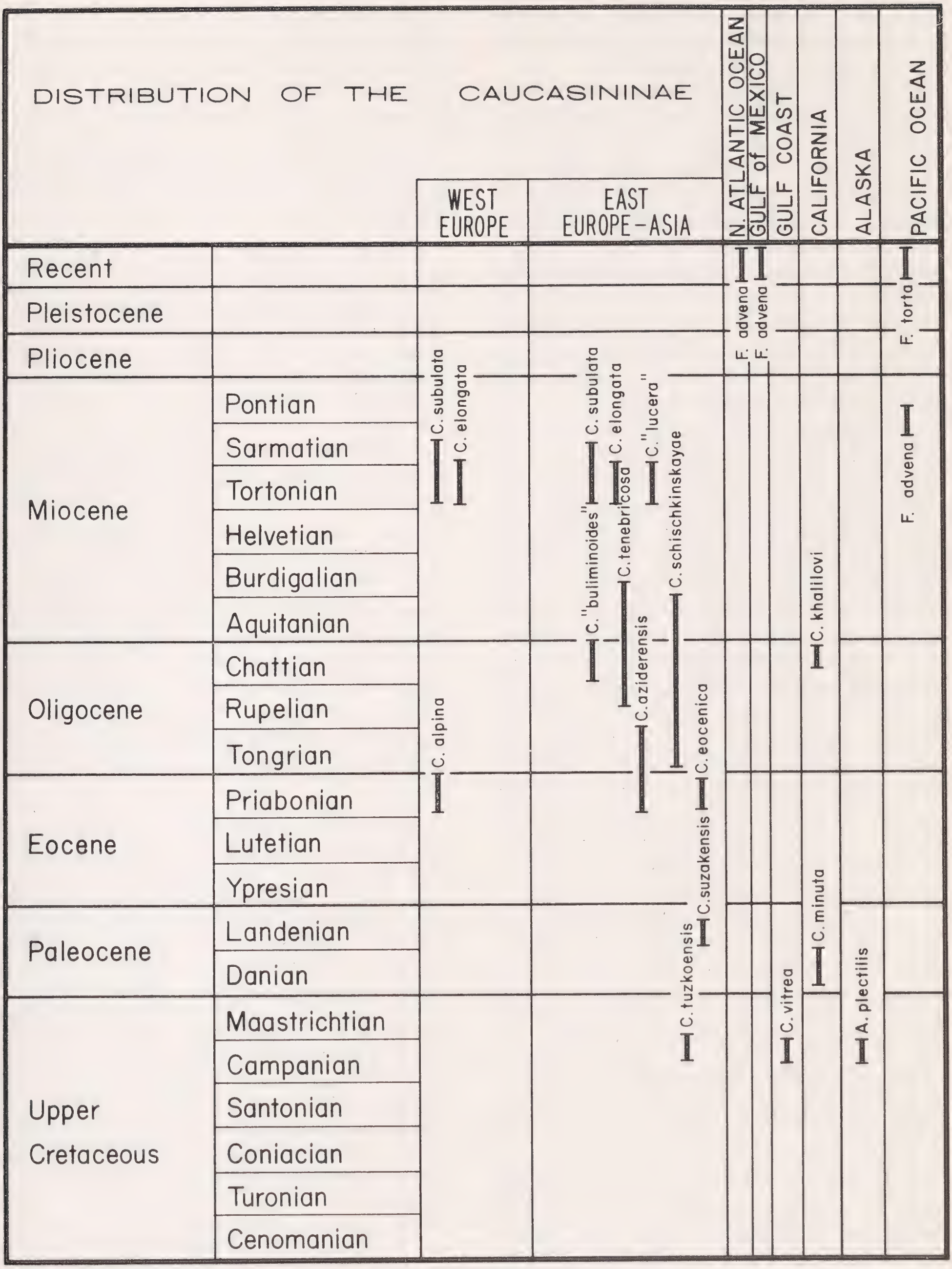
DISTRIBUTION OF THE CAUCASININAE
WEST EUROPE
EAST EUROPE-ASIA
N. ATLANTIC OCEAN
GULF of MEXICO
GULF COAST
CALIFORNIA
ALASKA
PACIFIC OCEAN
Recent
Pleistocene
Pliocene
Miocene
Pontian
Sarmatian
Tortonian
Helvetian
Burdigalian
Aquitanian
Oligocene
Chattian
Rupelian
Tongrian
Eocene
Priabonian
Lutetian
Ypresian
Paleocene
Landenian
Danian
Upper Cretaceous
Maastrichtian
Campanian
Santonian
Coniacian
Turonian
Cenomanian
F. advena
F. advena
F. torta
C. subulata
C. elongata
C. subulata
C. elongata
C. "buliminoides"
C. tenebricosa
C. "lucera"
C. aziderensis
C. schischkinskayae
C. alpina
C. eocenica
C. suzakensis
C. tuzkoensis
C. khalilovi
C. minuta
C. vitrea
A. plectilis
F. advena

FIGURE 2

the Lesser Caucasus. An upper Eocene species, *C. alpina,* also has been described from France (Espitalié and Sigal, 1961).

Additional Oligocene species are the type species *C. oligocenica* (here regarded as a synonym of *C. schischkinskayae,* as it has been by various workers, although recognized as a subspecies or distinct species by others), *C. schischkinskayae, C. tenebricosa,* and the apparently undescribed *C. "bulimi-noides." Caucasina schischkinskayae* has been widely reported from the Oligocene of the Crimea (Ukrainian SSR), Caucasus (Azerbaijan SSR), Armenian SSR, and the Kopet Dag (Turkmen SSR) (Samoylova, 1947; Khalilov, 1951, 1962; N. K. Bykova, 1953, 1959; Myatlyuk, 1960; Bogdanovich, 1960; Merklin, Morozova and Stolyarov, 1960; Chernyak, Bogaets, Voloshina and Khadikin, 1961; Kaptarenko-Chernousova, Golyak, Zernetskiy, Kraeva and Lipnik, 1963; Nosovskiy and Savenko, 1963; and Dmitriev and Kozhevnikova, 1963). It also has been reported in the lower Miocene of Abkhazii (northern Georgian SSR) by Dzhanelidze (1956).

Caucasina tenebricosa occurs in the Oligocene and in the mid-Miocene (Stebnikskoy beds) of the pre-Carpathians (Subbotina, Pishvanova and Ivanova, 1960, and Didkovs'kiy, 1963). References to two apparently undescribed species also occur frequently in the literature: *Caucasina "bulimi-noides"* has been reported from the Maykopskian beds (upper Oligocene) of the Crimea and Caucasus of the Ukrainian SSR and the Azov Kuban basin (Nikitina, 1962; Nosovskiy and Savenko, 1963) and from the Miocene (Burdigalian) of the northern Caucasus. Another form, *Caucasina "lucera,"* has been reported in the upper Tortonian (Tyachevskaya beds) of the trans-Carpathian area and Ukrainian SSR (Vyalov, Pishvanova, Petrashkevich and Grishkevich, 1962; Ivanova, 1962).

Bulimina elongata d'Orbigny from the Vienna Basin is widely reported in the Miocene of Europe and is here regarded as belonging to *Caucasina.* It has been referred to as *Neobulimina elongata* and as *"Caucasinella,"* in various publications, but the latter generic name has not been validated by a description, and the basis for its separation is not clear (N. K. Bykova, 1959; Myatlyuk, 1960; Nikitina, 1962).

An additional Austrian Miocene species, originally described as the "variety" *subulata of Bulimina elongata* is now regarded as a separate species and is here transferred to *Caucasina.* This basally spinose form also occurs in the trans-Carpathian region of the Ukrainian SSR, although there referred to *C. schischkinskayae* (Venglins'kiy, 1958).

Caucasina also has been reported from the Tortonian of Croatia, Yugoslavia (Sĭkić, 1962).

Because of the recognition of eleven valid species and three as yet undescribed, within the dozen years since the genus was described, it seems probable that additional species also will be found in other regions and strata, when their distinctive characters are noted.

IV. Ecologic Relationships

In some regions the abundance of specimens of *Caucasina* has led to recognition of a characteristic *Caucasina* complex. Other foraminifers commonly occurring with *Caucasina* include representatives of various agglutinated genera *(Bathysiphon, Spiroplectammina, Textularia, Haplophragmoides)* and *Rotalia, Valvulineria, Gyroidina, Heterolepa, Bulimina, Bolivina, Uvigerina* and *Nonion.* Ostracodes also may be present, as are such molluscan genera as *Leda, Tornatella, Ostrea, Natica, Planorbella* and *Dentalium.*

According to N. K. Bykova (1953, p. 270) the *Caucasina* complex in the Paleocene of Fergana occurs in a fine red clay deposit of very slight $CaCO_3$ content, formed under calm conditions in relatively shallow quiet waters, which may have been somewhat brackish. The sea bottom appears to have had an oxidizing environment. In some regions the *Caucasina* facies is associated with greenish-brown glauconitic clays (Kaptarenko-Chernousova, Golyak, Zernetskiy, Kraeva, and Lipnik, 1963). In nearly all regions radiolarians are found in association with the *Caucasina* complex or in nearby strata, and pelagic foraminifers may also be present.

The dominance of short low spired tests in some species, for example *Causasina minuta,* new species, is in contrast to the much more elongated test and higher spire of *C. elongata.* Such differences in proportion may in fact be related to the temperature conditions, as suggested by N. K. Bykova (1960), the short compact Paleocene forms thus being characteristic of relatively lower

temperatures, and the more elongate forms having appeared with the warmer conditions of the Oligocene-lower Miocene.

There is apparently a general correlation of occurrence of the *Caucasina* complex with moderate to warm temperature, as the genus has not been reported in cold water deposits. Although widespread and abundant in the Paleogene and Miocene, none has yet been recorded from the Pliocene, Pleistocene, or Recent.

V. Familial and Phylogenetic Relationships

The Subfamily Caucasininae was proposed within the Family Buliminidae by N. K. Bykova (in Rauzer-Chernousova and Fursenko, 1959, p. 328). Genera included were *Neobulimina, Caucasina, Uvigerinella, Hopkinsina,* and *Bitubulogenerina.* These were regarded as having in common a rotaloid base, later and dominantly triserial development which might become irregular or even biserial, and a loop-shaped subterminal aperture which nevertheless connects to the base of the apertural face. No neck is present, but an apertural flange was said to occur.

The subfamily was elevated to family rank (Loeblich and Tappan, 1961, p. 314), and removed from the Buliminidae because of the granular wall microstructure of *Caucasina* as contrasted with the radially crystalline wall of the Buliminidae. Of the genera originally placed in the subfamily, *Neobulimina* is now referred to the Family Turrilinidae, Subfamily Turrilininae, and *Uvigerinella, Hopkinsina,* and *Bitubulogenerina* (a junior synonym of *Sagrina*) to the Uvigerinidae, all with similar radially crystalline walls (Loeblich and Tappan, 1964). *Caucasina* was the single remaining genus in the subfamily until the Recent genus *Francesita* Loeblich and Tappan, 1963, was placed therein. In addition to the type species, *Virgulina? advena* Cushman, which occurs in the North Atlantic Ocean and Gulf of Mexico, the Recent *Bulimina torta* Cushman from the Pacific Ocean also appears referable to *Francesita,* and the genus may occur in Miocene deposits.

N. K. Bykova (1959, 1960) observed small rotaliform tests, described as similar to *Pseudoparrella,* associated with *Caucasina* in the Russian Paleocene. These *"Pseudoparrella"* were believed to have migrated from boreal regions into the Fergana Basin during the Paleocene (Pg_1). With progressive rise in temperature, the population became high-spired, and a reduction in number of chambers per whorl gave rise to *Caucasina.* A contemporary branch from *"Pseudoparrella"* was said to have led to species of *Turrilina* and then *Bulimina.* By mid-Eocene time *Caucasina* developed some nearly biserial forms. The lineage proposed by Bykova led from *"Pseudoparrella"* to *Caucasina* to *"Caucasinella"* (a *nomen nudum*), then to *Uvigerinella, Hopkinsina,* and finally *Uvigerina.*

Caucasina attained maximum development in Oligocene time according to Bykova, with three main groups appearing: an elongate form with well developed rotaloid early coil; another group of shortened and swollen tests, with obsolescent triserial stage; and a third group in which the number of chambers and number of whorls is greater than three, and with deeply incised sutures. These groups may be separate lineages, but may equally well represent different generations of the species.

Although originally agreeing with the facts known, the hypothesis of a Paleocene derivation of *Caucasina* from *Pseudoparrella* is no longer credible, as *Caucasina* is now known to have a longer geologic history, occurring in the Campanian (Upper Cretaceous). *Pseudoparrella* has a radially crystalline wall, similar to that of the Buliminidae and Uvigerinidae but unlike the granular-walled *Caucasina,* hence a relationship appears quite unlikely.

Normal variation within a local population may include numerous juvenile individuals, which may be erroneously regarded as distinct species or genera, and thus suggest different generic interrelationships. Although much remains to be learned before many lineages and interrelationships can be determined, it seems to us most probable that the origin of a given genus is most likely to be among those of similar biochemical constitution, as shown by the type of test secreted, and its chemical composition and microstructure. Thus the Caucasininae and Fursenkoininae are regarded as closely related, both groups of genera being characterized by calcite tests of perforate granular microstructure and monolamellar septa. Perhaps their origin may be found in such rotaliform genera of similar composition and microstructure as *Alabamina.*

VI. Acknowledgments

We are indebted to D. M. Khalilov, Institute of Geology, Academy of Sciences, Azerbaijan SSR, Baku, for topotypes of *Caucasina oligocenica* and to N. K. Bykova, VNIGRI, Leningrad, USSR, for specimens of *Caucasina schischkinskayae.* Specimens of *Aeolomorphella plectilis* are from a sample collected by C. A. Hall, Department of Geology, University of California, Los Angeles. Richard Cifelli, of the U. S. National Museum, loaned type specimens of *Bulimina elongata* and *Bulimina elongata* var. *lappa.* The Miocene specimens figured from Baden, Austria, were obtained from samples collected for the California Research Corporation by W. W. Hay. The Rincon material from Los Sauces Creek was collected by A. R. Loeblich, Jr., and the Dos Palos (Paleocene) material was from core holes drilled for us by the California Research Corp. in order to obtain unweathered material for foraminiferal studies.

All figured specimens are deposited in the paleontological collections at the University of California, Los Angeles. A duplicate set of hypotypes and paratypes is in the paleontological collections of Tulane University, New Orleans. The illustrations consist of shaded camera lucida drawings by Helen Tappan Loeblich.

VII. Systematic Descriptions

Family Caucasinidae N. K. Bykova, 1959

Subfamily Caucasininae N. K. Bykova, 1959

A. Genus Caucasina Khalilov, 1951

Caucasina Khalilov, 1951, Akad. Nauk Azerbaydzhanskoy SSR, Izvestiya, no. 3, p. 58; N. K. Bykova, 1959, Voprosy Paleobiologii i biostratigrafii, Trudy II sessii Vses. Paleontol. obshchestva, p. 73, text-fig. 3; N. K. Bykova and Voloshinova in Rauzer-Chernousova and Fursenko, 1959, Osnovy Paleontologii, pt. 1, p. 328; N. K. Bykova, 1960, Geol. Sbornik 5, Trudy VNIGRI, vyp. 163, p. 315; Loeblich and Tappan, 1961, Jour. Paleontology, v. 35, no. 2, p. 314; Espitalié and Sigal, 1961, Rev. Micropaléontologie, v. 3, no. 4, p. 203; Suleymanov, 1962, Paleontologicheskiy Zhurnal, no. 2, p. 163; Loeblich and Tappan, 1964, Treatise on Invertebrate Paleontology, Pt. C, Protista 2, v. 2, p. 734.

Aeolostrentis Loeblich and Tappan, 1957, U. S. Natl. Museum, Bull. 215, p. 227.

Type Species: *Caucasina oligocenica* Khalilov, 1951 = *Bulimina schischkinskye* Samoylova, 1947 *(recte B. schischkinskayae).* Fixed by original designation.

Test free, elongate, base bluntly rounded, early portion in low discorbine coil with up to 8 chambers per whorl, later portion high-spired with fewer chambers per whorl, becoming triserial in the later stage; early chambers low, later of approximately equal breadth and height and may be inflated; sutures distinct, commonly depressed in the later stages, may be flush in the early spiral portion; wall calcareous, finely perforate, microgranular in structure, surface smooth or may be coarsely spinose in the early stages; aperture an elongate loop at the inner margin of the final chamber, with narrow bordering lip, posterior apertural margin strongly infolded and flaring internally to form a distinct toothplate.

Remarks: Most later publications have erroneously cited the type species as *C. schischkinskayae.* The type was originally designated as *C. oligocenica,* hence cannot be changed. *Caucasina oligocenica* has been regarded by some later workers as a synonym of *C. schischkinskayae,* but by others is regarded as a variety [= subspecies] or as a distinct species, hence the type should be cited as *C. oligocenica.* If regarded as a synonym, the prior name *(C. schischkinskayae)* may be added as an equivalent, as given above, in type citations.

Occurrence: Upper Cretaceous (Campanian), USA, Asia; Paleocene, USA, USSR; Eocene, USSR, France; Oligocene, USSR, USA; Miocene, USSR, Austria, Croatia.

Described from the Oligocene, the geologic range of the type species was soon extended to include Miocene strata, and another species of this age was recently described (*C. tenebricosa* Pishvanova, 1960). In 1958, Khalilov extended the range to include the new Eocene-Oligocene species *C. aziderensis* and *C. eocenica,* and an additional Eocene species, *C. alpina,* was described from France in 1961. In 1957, Loeblich and Tappan described the genus *Aeolostreplis,* with *Buliminella vitrea,* from the Upper Cretaceous of the American Gulf Coast, as type species. The genus was later regarded (Loeblich & Tappan, 1961, p. 314) as synonymous with *Caucasina,* extending the generic range into the Upper Cretaceous. The following year *Caucasina tuzkoensis* was described from the Upper Cretaceous of Soviet Asia.

In the present study two additional Miocene species are transferred to *Caucasina (C. elongata* and *C. subulata),* a new Oligocene species is described from California *(C. khalilovi),* and the first lower Paleocene (Danian) occurrence noted with the description of *C. minuta.*

1. Upper Cretaceous Species

CAUCASINA TUZKOENSIS Suleymanov, 1962

Pl. 1, fig. 7

Caucasina tuzkoensis SULEYMANOV, 1962, Paleontologicheskiy Zhurnal, no. 2, p. 163, text-fig. 1a, b.

Test small, elongate, cylindrical, early trochospiral stage of two whorls, 6 small subquadrangular chambers in the first whorl, and 5 in second, later development in a high trochospiral coil of which the first whorl contains 4 chambers and the final whorl three, test tending to uncoil in the later stage; sutures simple, straight and oblique, nearly flush with the surface; wall calcareous, vitreous, perforate, microgranular, surface smooth; aperture a broad loop in the face of the final chamber, somewhat narrowed at the base.

Length 0.22-0.24 mm; breadth 0.1-0.15 mm.

Types and Occurrence: Holotype (VNI GRI, Leningrad, No. 517-3), Upper Cretaceous (upper Campanian), Tashkudukskaya beds, Kyzyl Kum, central Asia.

CAUCASINA VITREA (Cushman and Parker)

Pl. 1, figs. 5, 6

Buliminella vitrea CUSHMAN and PARKER, 1936, Cushman Lab. Foram. Research, Contr., v. 12, p. 7, pl. 2, fig. 4; CUSHMAN, 1946, U. S. Geol. Survey, Prof. Paper 206, p. 119, pl. 50, fig. 14; CUSHMAN and PARKER, 1947, U. S. Geol. Survey, Prof. Paper 210-D, p. 59, pl. 15, fig. 12; FRIZZELL, 1954, Univ. Texas, Bur. Econ. Geol., Rept. Invest. 22, p. 114, pl. 16, fig. 42.

Aeolostreptis vitrea (Cushman and Parker). LOEBLICH and TAPPAN, 1957, U. S. Natl. Museum, Bull. 215, p. 227, pl. 72, fig. 20.

non *Aeolostreptis vitrea* (Cushman and Parker). TAPPAN, 1960, Amer. Assoc. Petr. Geol., v. 44, no. 3, p. 285, 289.

non *Caucasina vitrea* (Cushman and Parker). TAPPAN, 1962, U. S. Geol. Survey, Prof. Paper 236-C, p. 188, pl. 49, figs. 23-25.

Test free, elongate, base bluntly rounded, early portion in low trochospiral coil of about 6 broad and low chambers per whorl, later decreasing to three chambers per whorl with chambers relatively high; sutures distinct, depressed in the later portion; wall calcareous, perforate, surface smooth; aperture a high arch extending up the final chamber face from the contact with the previous whorl.

Length of holotype 0.25 mm; other specimens from 0.16 to 0.25 mm in length, 0.08 to 0.15 mm in breadth.

Types and Occurrence: Holotype (Cushman Coll. 22575, U. S. Natl. Museum) from the Selma Chalk (Upper Cretaceous), 2 miles west of Guntown, Mississippi. Figured hypotype (Cushman Coll. 32549, U. S. Natl. Museum) from the Selma Group, 11.5 miles east of Blue Springs, Mississippi. It also has been reported from the Upper Cretaceous (upper Austin) of Texas.

2. Paleocene Species

CAUCASINA MINUTA Loeblich and Tappan, n. sp.

Pl. 1, figs. 8-11

Test free, tiny, elongate, base broadly rounded, early portion consisting of a low trochospiral coil of about 3 volutions and 5 to 6 chambers per whorl, later portion subcylindrical and high spired; sutures distinct, slightly depressed; wall calcareous, finely perforate, surface smooth; aperture a loop shaped arch with posterior margin forming an infolded toothplate.

Length of holotype 0.18 mm, breadth 0.10 mm. Other specimens range between 0.11 and 0.15 mm in length.

Remarks: This species is the smallest yet described, somewhat resembling the Oligo-Miocene *C. schischkinskayae* in general form and proportions, but with less inflated chambers and less depressed sutures, and is less than one-half as large. It also has a more gradual change from trochospiral to triserial development.

Types and Occurrence: Holotype (UCLA 34220) from depth of 255 feet, figured paratypes (UCLA 34221-34223) from depth of 260 feet, Dos Palos Shale Member of Moreno Formation, in core hole in Panoche Hills, Sec. 8, T. 15S., R. 12E., M.D.M., Fresno Co., Calif.; collected by A. R. Loeblich, Jr.

3. Eocene Species

CAUCASINA ALPINA Espitalié and Sigal, 1961

Pl. 1, figs. 14-15

Caucasina alpina ESPITALIÉ and SIGAL, 1961, Rev. Micropaléontologie, v. 3, no. 4, p. 204, pl. 1, figs. 9a-d.

Test very small, base obtuse, rapidly increasing in breadth, final whorl occupying at least ¾ test length; earliest 1½ whorls low spired with 5 to 5½ chambers per whorl,

then high spired with 3 strongly inflated chambers per whorl; sutures deeply incised, curved; wall calcareous, vitreous, finely perforate; aperture in a large buliminoid depression.

Length 0.30 to 0.39 mm; breadth 0.18 to 0.24 mm.

Remarks: This species was separated on the basis of the rapid enlargement of the test, relative importance of the final whorl, and in having 5 to 5½ chambers in the early whorl.

Types and Occurrence: Upper Eocene (Upper Priabonian), Blue Marls, Clouet, near Clumanc (Basses-Alpes), France.

CAUCASINA AZIDERENSIS Khalilov, 1958

Pl. 1, fig. 12

Caucasina aziderensis KHALILOV, 1958, Akad. Nauk Azerbaydzhanskoy SSR, Izvestiya, Ser. Geol. Geogr. Nauk, no. 2, p. 4, 12, pl. 1, figs. 3a, b.

Test elongate, flaring, high trochospiral; following the globular proloculus the first whorl consists of 4 to 4½ semicircular chambers, later whorls reduced to 3½ to 4 chambers each, final 2 or 3 whorls each with 2 to 3 subglobular chambers; sutures narrow, curved, incised; wall calcareous, surface distinctly perforate; aperture elongate-ovate, a high loop with bordering lip, extending up the final chamber face.

Length 0.4 mm; greatest thickness 0.24 mm.

Types and Occurrence: Holotype (No. 339, Microfaunal collection, Institute of Geology, Akad. I. P. Gubkin, Academy of Science, Azerbaijan SSR) from upper Eocene-lower Oligocene deposits, in the northeast foothills of the Lesser Caucasus, Azerbaijan.

CAUCASINA EOCAENICA Khalilov, 1958

Pl. 1, fig. 13

Caucasina eocaenica KHALILOV, 1958, Akad. Nauk Azerbaydzhanskoy SSR, Izvestiya, Ser. Geol.-Geogr. Nauk, no. 2, p. 4, 12, pl. 1, figs. 2a, b; KHALILOV, 1962, Akad. Nauk Azerbaydzhanskoy SSR, Inst. Geol. im Akad. I. M. Gubkina, p. 30; NIKITINA, 1962, Byull. Moskov. obshch. Ispyt. Pri-

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PLATE 1

Figures		Page
1–4	*Aeolomorphella plectilis* Loeblich and Tappan, n. gen., n. sp. Sentinel Hill Member, Schrader Bluff Formation, Upper Cretaceous, northern Alaska. 1a-c, side, top and basal views of paratype (USNM P6681) originally referred to *Caucasina vitrea.* 2a-d, side edge, top and basal views of holotype (UCLA 34237) showing early trochospiral coil and final biserial development, 3, side view of smaller paratype (UCLA 34238). 4, a, b, side and basal view of juvenile specimen (UCLA 34239). All x 120	84
5–6	*Caucasina vitrea* (Cushman and Parker). Selma Chalk, Upper Cretaceous, Mississippi. 5a-c, opposite sides and apertural view of holotype (Cushman Coll. 22575), redrawn from Cushman and Parker, x 130. 6a-c, side, apertural and basal views of hypotype (Cushman Coll. 32549), redrawn from Loeblich and Tappan. x 140	75
7	*Caucasina tuzkoensis* Suleymanov. Tashkudukskaya beds, upper Campanian, Upper Cretaceous, Kyzyl Kum, central Asia, USSR. 7a, b, side and basal views of holotype, redrawn from Suleymanov. x 120	75
8–11	*Caucasina minuta* Loeblich and Tappan, n. sp. Dos Palos Shale member of Moreno Formation, lower Paleocene (Danian), California. 8, 9, 11a, side views of small paratypes. 11b, basal view (UCLA 34221-34223). 10a-c, side, top and basal views of holotype (UCLA 34220). All x 180	75
12	*Caucasina aziderensis* Khalilov. Upper Eocene, Lesser Caucasus, Azerbaijan SSR. 12a, b, side and basal views of holotype, redrawn from Khalilov. x 70	76
13	*Causasina eocaenica* Khalilov. Upper Eocene, Lesser Caucasus, Azerbaijan SSR. 13a, b, side and basal views of holotype. Redrawn from Khalilov. x 70	76
14–15	*Caucasina alpina* Espitalié and Sigal. Priabonian blue marls, upper Eocene, Basses-Alpes, France. 14a-d, opposite sides, top and basal views of holotype. x 110. 15, side view of paratype. x 120. Redrawn from Espitaliè and Sigal	75

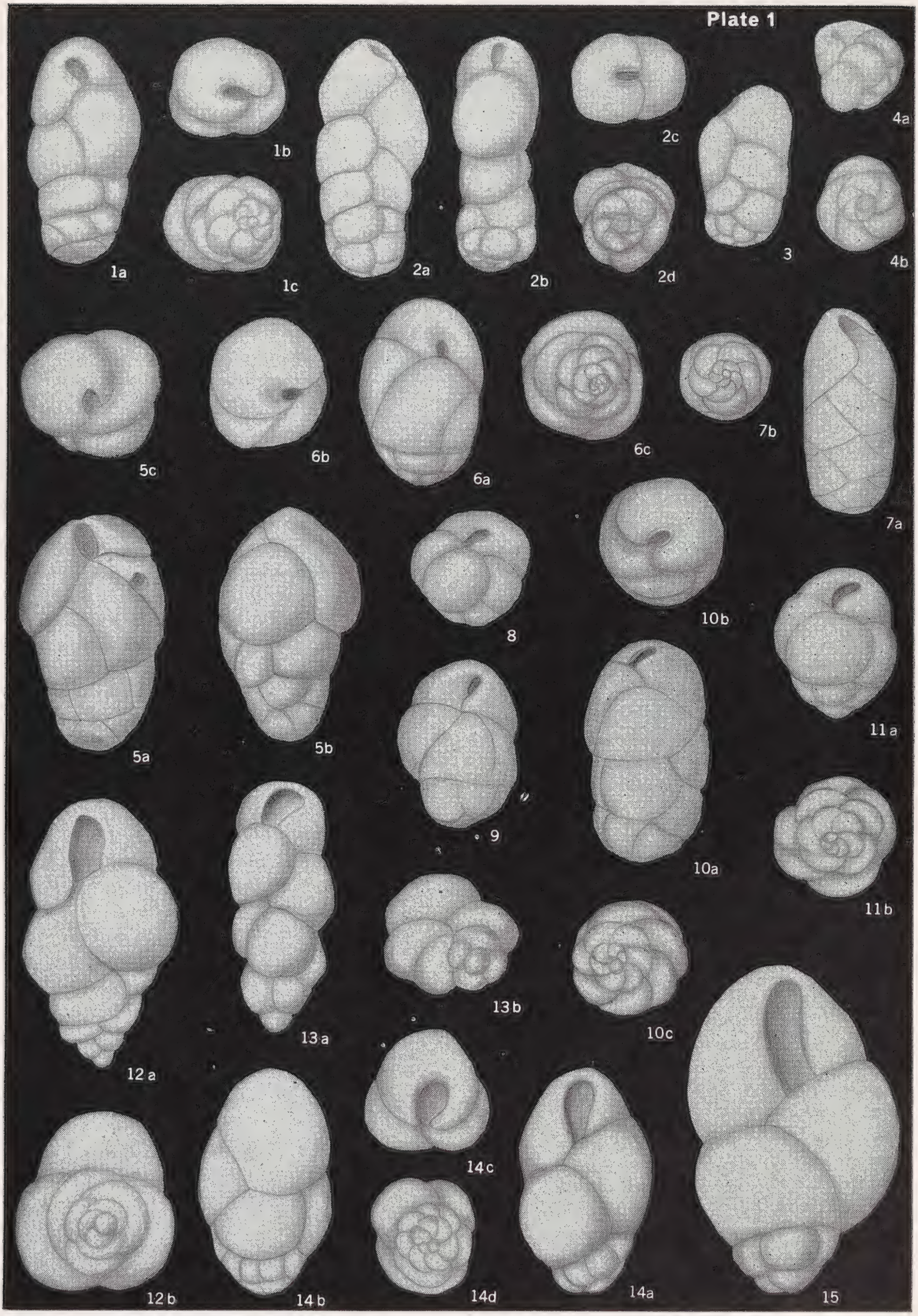
Plate 1
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PLATE 1

rody, otdel. geol., v. 37, no. 2, p. 50, 52, 57; NIKITINA, 1963, ibid., v. 38, no. 1, p. 97, 104.

Test elongate, narrow, high spired, tapered at the base, early one or two whorls consist of 4 to 5 rounded chambers per whorl, later 2 to 4 whorls more highly spired and loosely triserial, inflated chambers tend to become uniserial; sutures strongly incised; wall calcareous, vitreous, distinctly perforate; aperture a high, broad loop in the apertural face, irregularly ovate in outline, narrowing at the base.

Length 0.48 mm; greatest thickness 0.17 mm.

Types and Occurrence: Holotype (No. 338, Microfaunal collection of the Institute of Geology, Akad. I. P. Gubkin, Academy of Science, Azerbaijan SSR), Upper Eocene (occurring with *Globigerina turkmenica* and *Globigerinoides conglobatus*) in the northeast foothills of the Lesser Caucasus, eastern Azerbaijan, USSR.

4. Oligocene Species

CAUCASINA KHALILOVI Loeblich and Tappan, n. sp.

Pl. 2, figs. 7-9

Test small, elongate, only slightly increasing in diameter from the bluntly rounded base, early stage in a low trochospiral coil of 1½ to 2 volutions and about 5 chambers per whorl, then rapidly reducing to triserial and becoming high spired with subglobular chambers; sutures depressed; wall calcareous, finely perforate, surface smooth; aperture a high loop-shaped opening extending up the apertural face from its base, bordered by a narrow lip with forward margin overlapping that opposite at its base.

Length of holotype 0.24 mm; breadth 0.13 mm. Paratypes range from 0.13 to 0.29 mm in length.

Remarks: This species differs from *C. schischkinskayae* in the smaller size, fewer chambers per whorl and more rapid reduction to triseriality. It is separated from *C. tenebricosa* by its smaller size, proportionately narrower test, and more numerous chambers per whorl in the early trochospiral stage.

Types and Occurrence: Holotype (UCLA 34224) and figured paratypes (UCLA 34225-34226) all from the lower portion of the Oligocene Rincon formation, regarded by some as Lower or Middle Miocene (Wilmarth, 1938, p. 1815), in bed of Los Sauces Creek, Ventura Co., California; collected by A. R. Loeblich, Jr.

CAUCASINA TENEBRICOSA Pishvanova *in* Subbotina, Pishvanova and Ivanova, 1960

Pl. 2, figs. 5-6

Caucasina tenebricosa PISHVANOVA *in* SUBBOTINA, PISHVANOVA and IVANOVA, 1960, Mikrofauna SSSR, Sbornik 11, Trudy VNIGRI, vyp. 153, p. 90, pl. 6. figs. 2a-c; SUBBOTINA, 1960, Mikrofauna SSSR, Sbornik 11, Trudy VNIGRI, vyp. 153, p. 212, pl. 4, figs. 2a-4c; LESHCHINSKIY, A. A. 1960, Opornye Skvazhiny SSSR, 1, Trudy VNIGRI, vyp. 24, p. 215, 226; DIDKOVS'KIY, 1963, Geol. Zhurnal, Akad. Nauk Ukraïns'koï RSR, Khimich. i Geologich. Nauk, v. 23, no. 2, p. 98.

Test free, small, elongate, bluntly rounded at base and enlarging slightly toward the aperture, peripheral margin slightly lobulate; chambers in high trochospiral coil of 4 to 6 whorls, early rotaloid portion of 2 to 2½ whorls contains 4 to 5 rounded chambers per whorl, later portion of test triserial with chambers increasing rapidly in size; sutures distinct, oblique, slightly excavated; wall calcareous, finely perforate, surface smooth; aperture a high loop in a trough-like excavation in the final chamber face.

Length 0.96 to 1.06 mm; breadth 0.53-0.59 mm.

Types and Occurrence: Holotype (VNI GRI, Leningrad, No. 5197), from Oligocene (lower Vorotyshchensky beds), in the Pre-Carpathians, Dzvinyach village, USSR. Also occurs in middle Miocene (Slebniksky beds) of the Pre-Carpathians.

5. Oligo-Miocene Species

CAUCASINA SCHISCHKINSKAYAE (Samoylova), 1947

Pl. 2, figs. 1-4

Bulimina schichkinskii SAMOYLOVA, 1947, Byull. Moskov. Obshch. Ispyt. Prirody, otdel. geol., v. 21, no. 2, p. 52 (table 4) *(nom. nud.)*.

Bulimina schischkinskii SAMOYLOVA, 1946, ibid., v. 21, no. 2, p. 54 *(nom. nud.)*.

Bulimina schischkinskye SAMOYLOVA, 1947, ibid., v. 22, no. 4, p. 82, text-fig. 10; GABRIELYAN, 1954, Geol. Sbornik, L'vovskogo Geol. Obshch. no. 1, p. 140; N. K. BYKOVA and VOLOSHINOVA *in* RAUZER-CHERNOUSOVA and FURSENKO, 1959, Osnovy Paleontologii, Obshchaya Chast', Prosteyshie, p. 328 *(nom. imperf.)*.

Caucasina oligocenica KHALILOV, 1951, Akad. Nauk Azerbaydzhanskoy SSR, Izvestiya, no. 3, p. 58, pl. 4, fig. 4.

Caucasina schischkinskae (Samoylova). N. K. BYKOVA, 1953, Trudy VNIGRI, n. ser., vyp. 73, p. 223, 267, table 8; N. K. BYKOVA, 1960, Geol. Sbornik, no. 5, Trudy VNIGRI, vyp. 163, p. 316, pl. 2, B 1-8; N. K. BY-

KOVA and AZBEL', 1962, Geol. Sbornik, no. 7, Trudy VNIGRI, vyp. 190, p. 377, 381 (table), 385 (fig. 2), 387, 388, 390, 391, 393 (table) *(nom. imperf.)*.

Caucasina aff. *schischkinskae* (Samoylova). GEKKER, OSIPOVA and BEL'SKAYA, 1962, Ferganskiy zaliv paleogenovogo morya sredney azii, ego istoriya, osadki, fauna, flora, usloviya ikh obitaniya i razvitie: Knigi 1, Akad. Nauk SSSR, Paleontol.-Inst., p. 73, 271; *ibid.*, Knigi 2, p. 6 (table 1), 9, 16, text-fig. 2a, p. 18, 264 *(nom. imperf.)*.

Caucasina schischkinskyae (Samoylova). DZHANELIDZE, 1956, Akad. Nauk Gruzinskoy SSR, Trudy Sektora Paleobiol., v. 3, p. 93, 122; IVANOVA, 1956, Geol. Sbornik, L'vovskogo Geol. Obshch., no. 2-3, p. 327; NOSOVSKIY and YARTSEVA, 1960, Paleogenovye otlozheniya yuga Evropeyskoy chasti SSSR, Akad. Nauk SSSR, p. 183, 184; BOGDANOVICH, 1960, ibid., table opposite p. 246, p. 249, 250, 251, 252, 253, 254, 255, 256, 258, 269, pl. 4, figs. 3-5; MYATLYUK, 1960, Trudy Pervogo Seminara po Mikrofaune, VNIGRI, p. 208; GABRIELYAN, SAAKYAN and MARTIROSYAN, 1960, ibid., p. 305; OVECHKIN, 1962, Vses. Nauchno-Issledov. Geol. Inst. (VSEGEI), Trudy, n. ser. v. 77, p. 194, 234; KAPTARENKO-CHERNOUSOVA, GOLYAK, ZERNETSKIY, KRAEVA and LIPKNIK, 1963, Akad. Nauk Ukraïnskoï SSR, Inst. Geol. Nauk, ser. stratig. i paleontol., vyp. 45, p. 165, pl. 47, figs. 5-7; DMITRIEV and KOZHEVNIKOVA, 1963, Akad. Nauk Turkmenskoy SSR, Izvestiya, ser. Fiz.-Technich., Kimich. i Geol. Nauk, no. 2, p. 103, 106; VESELOV and KRAEVA, 1963, Akad. Nauk Ukraïns'koï RSR, Geol. Zhurnal, v. 23, vip. 4, p. 42 *(nom. imperf)*.

Caucasina aff. *schischkinskyae* (Samoylova). DZHANELIDZE, 1956, Akad. Nauk Gruzinskoy SSR, Trudy Sektora Paleobiol., v. 3, p. 92, 93, 121, pl. 3, figs. 7a, b *(nom. imperf.)*.

Caucasina aff. *schischknskyae* (Samoylova). DZHANELIDZE, 1956, ibid., p. 113 *(nom. imperf.)*.

Caucasina schisckinskyae DZHANELIDZE, 1956, ibid., p. 113 *(nom. imperf.)*.

Caucasina schischkinskayae (Samoylova). KHALILOV, 1958, Akad. Nauk Azerbaydzhanskoy SSR, Izvestiya, Ser. Geol.-Geogr. Nauk, no. 2, p. 4 (*nom. correct.* pro *Bulimina schischkinskye* Samoylova, 1947); MERKLIN, MOROZOVA and STOLYAROV, 1960, Doklady Akad. Nauk, v. 133, no. 3, p. 654, 655.

Caucasina oligocaenica Khalilov. KHALILOV, 1958, Akad. Nauk Azerbaydzhanskoy SSR, ser. Geol.-Geogr. Nauk, no. 2, p. 3, 12, pl. 1, fig. 1; KHALILOV, 1962, Mikrofauna i stratigrafiya paleogenovykh otlozhenii Azerbaydzhana, Akad. Nauk Azerbaydzhanskoy SSR, Inst. Geol. im Akad. I. M. Gubkina, p. 40; ESPITALIÉ and SIGAL, 1961, Rev. Micropaléontologie, v. 3, no. 4, p. 204, pl. 1, figs 1-8 (*err. cit.* pro *C. oligocenica* Khalilov, 1951).

Caucasina schischkinkiae (Samoylova). NIKITINA, 1958, Izvest. Vysshikh Uchebnykh Zavedeniy Geol. i Razvedka, no. 7, p. 52 *(nom. imperf.)*.

Caucasina schischkinskiae (Samoylova). NIKITINA, 1958, ibid., p. 45, 46, 48, 49, 52; BOGDANOVICH, 1960, Trudy Vses. Neftegaz. Nauchno-Issledov. Inst. Krasnodarskiy Filial, vyp. 4, Geol. Sbornik, p. 241; TER-GRIGOR'YANTS, 1961, Trudy VNIGRI, vyp. 30, p. 271 *(nom. imperf.)*.

Caucasina aff. *schischkinskiae* (Samoylova). NIKITINA, 1958, Izvest. Vysshikh Uchebnykh Zavedeniy Geol. i Razvedka, no. 7, p. 46, 52.

Caucasina schischkincskajae (Samoylova). N. K. BYKOVA and VOLOSHINOVA *in* RAUZER-CHERNOUSOVA and FURSENKO, 1959, Osnovy Paleontologii, Obshchaya Chast', Prosteyshie, text-fig. 799a, b *(nom. imperf.)*.

Caucasina schischkinskye (Samoylova). YARTSEVA, 1959, Geol. Zhurnal, Akad. Nauk Ukraïns'koï RSR, v. 19, vyp. 3, p. 29, 30, 31, 32, 33, 35; SELIN, 1960, *ibid.*, v. 20, vyp. 4, p. 105; ESPITALIÉ and SIGAL, 1961, Rev. Micropaléontologie, v. 3, no. 4, p. 203, 206 *(nom. imperf.)*; DABAGYAN, 1961, Paleont. Sbornik, L'vov. Geol. Obshch., No. 1, p. 98, 99.

Caucasina schischkinshkye (Samoylova). YARTSEVA, 1959, Geol. Zhurnal, Akad. Nauk Ukraïns'koï RSR, v. 19, vyp. 3, p. 31 *(nom. imperf.)*.

Caucasina schichkinskyae (Samoylova). KRAEVA, 1960, Paleogenovye otlozheniya yuga Evropeyskoy chasti SSSR, Akad. Nauk SSSR, p. 236 *(nom. imperf.)*.

Caucasina shishkinskiae (Samoylova). YANSHIN, VYALOV, DOLGOPOLOV and MENNER, 1960, ibid., table 2 (opposite p. 9) *(nom. imperf.)*.

Caucasina schisckhinshkyae (Samoylova). BOGDANOVICH, 1960, Paleogenovye otlozheniya yuga Evropeyskoy chasti SSSR, Akad. Nauk SSSR, p. 254 *(nom. imperf.)*.

Caucasina schischkiskiae (Samoylova). TER-GRIGOR'YANTS, 1961, Trudy VNIGRI, vyp. 30, p. 268, 270 *(nom. imperf.)*.

Caucasina schischkinskajae (Samoylova). CHERNYAK, BOGAETS', VOLOSHINA, and KHADIKIN, 1961, Geol. Zhurn., Akad. Nauk Ukraïn. RSR, v. 21, vyp. 2, p. 84; NOSOVSKIY, 1963, Byull. Moskov. Obshch. Ispyt. Prirody, otdel. geol., v. 38, no. 5, p. 8, 10 *(nom. imperf.)*.

Caucasica [sic] *schischkienskajae* (Samoylova). KRAEVA, 1961, Foram. Verkhn'oeotsenovikh ta Oligotsenovikh vidkladiv . . . p. 29 *(nom. imperf.)*.

Caucasina schishkinskae (Samoylova). SULEYMANOV, 1962, Paleontologicheskiy Zhurnal, no. 2, p. 163 *(nom. imperf.)*.

Caucasina schischkinskayae (Samoylova) var. *oligocaenica* Khalilov. KHALILOV, 1962, Mikrofauna i stratigrafiya paleogenovykh otlozhenii Azerbaydzhana, Akad. Nauk Azerbaydzhanskoy SSR, Inst. Geol. im Akad. I. M. Gubkina, p. 168, 184, 195, 196, 202, 203, 210, 211, 298, 302, 303, 304

(var. = infrasubspecific rank after Jan. 1961, hence excluded from zoological nomenclature. ICZN Art. 45 (c) (e) & Art. 1; *nom. imperf.*).

Caucasina schischkynskayae (Samoylova) var. *oligocaenica* Khalilov. KHALILOV, 1962, ibid., p. 251, 302 (see remarks in synonomy above; *nom. imperf.*).

Caucasina cf. *schischkinskajae* (Samoylova). NIKITINA, 1962, Byull. Moskov. Obshch. Ispyt. Prirody, otdel. geol., v. 37, no. 2, p. 58 *(nom. imperf.)*.

Caucasina schischkienskyae (Samoylova). NOSOVSKIY and SAVENKO, 1963, Doklady Akad. Nauk SSSR, v. 148, no. 5, p. 1179, 1180 *(nom. imperf.)*.

Caucasina schischinskajea (Samoylova). NOSOVSKIY, 1963, Byull. Moskov. Obshch. Ispyt. Prirody, otdel. geol., v. 38, no. 5, p. 14 *(nom. imperf.)*.

non *Caucasica* aff. *schischkinskae* (Samoylova). N. K. BYKOVA, 1953, Trudy VNIG RI, n. ser., vyp. 73, p. 266 *(nom. imperf.)*.

non *Caucasina* aff. *schischkinskae* (Samoylova). N. K. BYKOVA, 1953, Trudy VNI GRI, n. ser., vyp. 73, p. 223, 225, 263, 267, 273, pl. 5, figs. 11-13, pl. 6, fig. 2.

non *Caucasina schischkinskye* (Samoylova). VENGLINS'KIY, 1958, Foraminiferi Miotsenu Zakarpattya, Akad. Nauk Ukraïns'koï RSR, Inst. Geol. Korisnikh Kopalin, p. 33, 135, table 3, pl. 29, figs. 4-9. [= *C. subulata*]

Test free, robust, subcylindrical, base broadly rounded; early stage in low trochospiral coil of about 3 whorls, with 5 to 7 chambers per whorl, later portion of test of somewhat lesser diameter and higher spired in microspheric form, slightly flaring in megalospheric generation, later portion triserial; chambers of early portion broad and low, in adult stage much inflated and of about equal breadth and height; sutures distinct, depressed, spiral suture nearly horizontal with septal sutures gently curved; wall calcareous, finely perforate, granular, surface smooth; aperture a high loop-shaped opening extending up final chamber face, forward apertural margin somewhat overlapping posterior margin near the chamber base, inner posterior margin infolded to form an apertural toothplate.

Length of juvenile specimen, showing only the trochospiral coiled stage, 0.11 mm; breadth 0.14 mm. Length of larger specimen 0.37 mm; breadth 0.18 mm. Length of specimen of fig. 4, 0.50 mm.

Remarks: This species has been widely recorded (see above synonymy) in the Oligocene-Miocene of the USSR, where it

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PLATE 2

Figures — Page

1–4 *Caucasina schischkinskayae* (Samoylova). 1-3, hypotypes of *C. oligocenica* (UCLA 34227-34229), Oligocene Azerbaijan SSR. 4, hypotype of *C. schischkinskayae* (UCLA 34230), Oligocene, Mangyshlak well, USSR. 1a-c, side, top and basal views of large hypotype. 2a, b, side and top views of juvenile specimens. 3, side view. All x 115. 4, side view of large specimen, x 80 ---- 78

5–6 *Caucasina tenebricosa* Pishvanova. Lower Vorotyshchensky beds, Oligocene, pre-Carpathians, USSR. 5a-c, opposite sides and base of microspheric holotype, redrawn from Subbotina, Pishvanova and Ivanova, x 85. 6a-c, opposite sides and base of megalospheric specimen, redrawn from Subbotina, x 120 78

7–9 *Caucasina khalilovi* Loeblich and Tappan, n. sp. Rincon Formation, Oligocene, California. 7a-c, side, top and basal views of holotype (UCLA 34224). 8, 9, side and basal views of paratypes (UCLA 34225-34226). All x 120 78

10–13 *Caucasina subulata* (Cushman and Parker). Badener Tegel, Tortonian, Miocene, Austria. 10a-c, side, top and basal views of large topotype with slightly spinose base (UCLA 34233). 11a, c, side and base of topotype with few spines (UCLA 34234). 12a, b, side and base of strongly spinose topotype (UCLA 34235). All x 60. 11b, enlarged view of apertural region to show overlapping basal margin and narrow lip. 13a, side view of apertural region of topotype (UCLA 34236) with outer apertural rim broken to show infolded toothplate which broadens internally (compare to fig. 11b). 13b, top view of same viewed in partially transmitted light, showing the infolded toothplate within the final chamber, just above the apertural margin as oriented in the figure. Figs. 11b, 13a, b, x 180 ---- 83

14–15 *Caucasina elongata* (d'Orbigny). Badener Tegel, Tortonian, Miocene, Austria. 14a, b, side and basal views of hypotype (UCLA 34231). 15a-c, side, top and basal views of hypotype (UCLA 34232). Both x 60 ---- 82

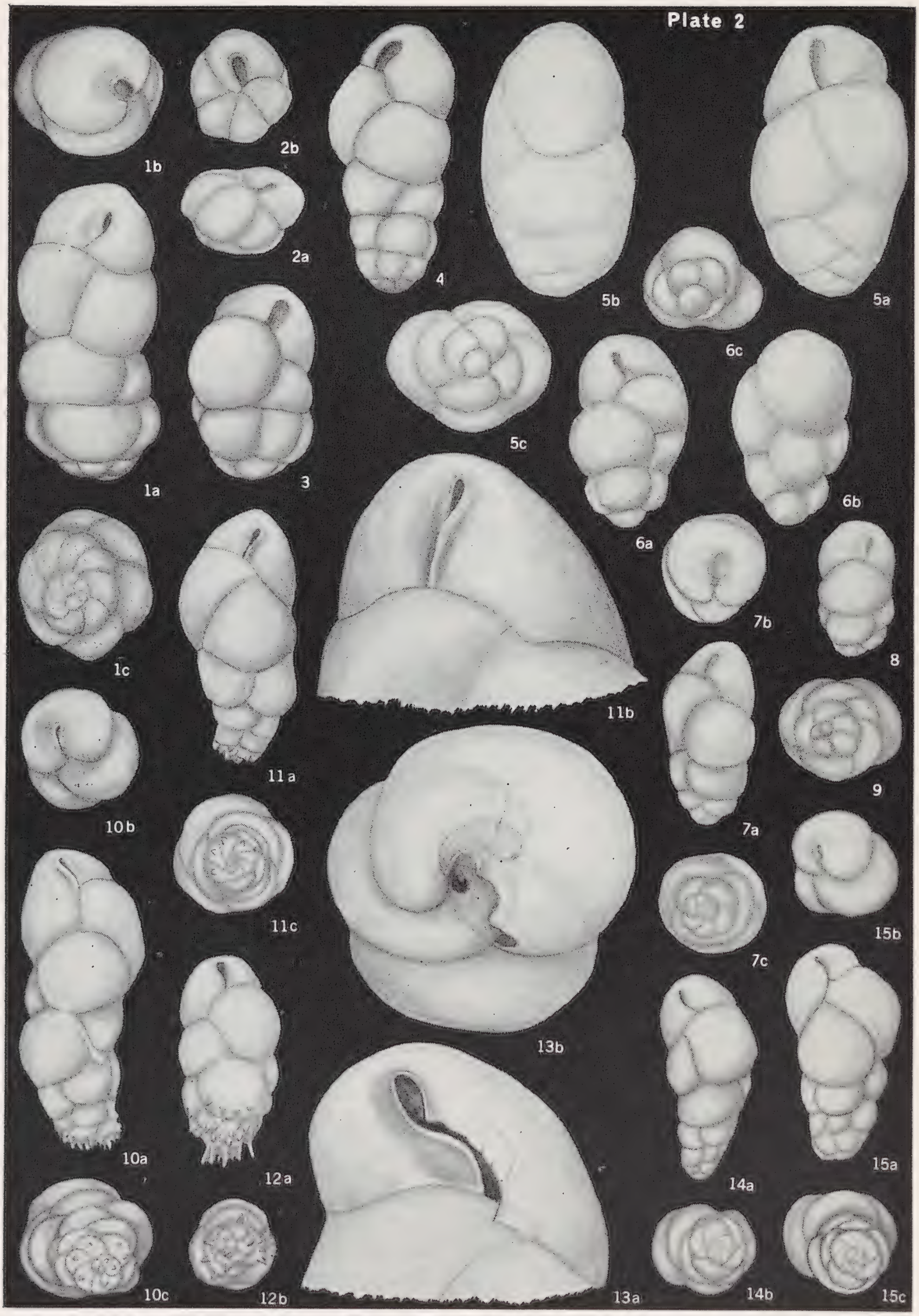
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PLATE 2

is regarded as a zonal index fossil. The above cited record of *C.* aff. *schischkinskae* by N. K. Bykova (1953) from the Paleocene Suzaksky beds of Fergana is not this species, but may be the same as *C. "suzakensis,"* cited in recent publications but apparently not yet described.

Originally described as *Bulimina schischkinskye,* the species had been listed earlier as *B. schischkinskii (nomen nudum),* but as a feminine patronymic required correction to *schischkinskayae,* as was done by Khalilov, 1958. The type species of the genus, *Caucasina oligocenica,* is regarded by many as a synonym of *B. schischkinskayae,* as it is here. Some 30 different combinations and variant spellings (including misprints and erroneous emendations) have been used for this species during the past 17 years.

Types and Occurrence: Hypotypes (figs. 1-3) of *C. oligocenica* (UCLA 34227-34229) from the Oligocene of Zeiva, Village, Azerbaijan SSR; from D. M. Khalilov. Hypotype (fig. 4) of *C. schischkinskayae* (UCLA 34230) from Mangyshlak well, USSR; from N. K. Bykova.

6. Miocene Species

CAUCASINA ELONGATA (d'Orbigny)

Pl. 2, figs. 14-15

Bulimina elongata D'ORBIGNY, 1846, Foram. fossiles bassin tertiaire de Vienne, p. 187, p. 11, figs. 19-20; CUSHMAN and PARKER, 1937, Cushman Lab. Foram. Res., Contr., v. 13, p. 49, pl. 7, figs. 1-3 (in part, not including all synonymy); DZHANELIDZE, 1956, Akad. Nauk Gruzinskoy SSR, Trudy Sektora Paleobiol., v. 3, p. 95, 122; VENGLINS'KIY, 1958, Foraminiferi Miotsenu Zakarpattya, Akad. Nauk, Ukraïns'koï RSR, Inst. Geol. Korisnikh Kopalin, p. 132, pl. 28, fig. 3, pl. 29, figs. 1, 2; KUZNETSOVA, 1959, Voprosy Paleobiologii i Biostratigrafii, Trudy II Sessii Vses. Paleontol. obshchestva, p. 107; MYATLYUK, 1960, Trudy Pervogo Seminara po Mikrofaune, VNIGRI, p. 211; SUBBOTINA, PISHVANOVA and IVANOVA, 1960, Mikrofauna SSSR, Sbornik 11, Trudy VNIGRI, vyp. 153, p. 83, pl. 5, figs. 12, 13 (not 14, 15); VYALOV, PISHVANOVA, PETRASHKEVICH and GRISHKEVICH, 1962, Byull. Moskov. obshch. Ispyt. Prirody, otdel. geol., v. 37, no. 5, p. 71, 72, 73, 75.

Neobulimina elongata (d'Orbigny). SUBBOTINA, 1953, Mikrofauna SSSR, Sbornik 6, Trudy VNIGRI, vyp. 69, p. 217, pl. 9, figs. 12-14; N. K. BYKOVA, 1959, Voprosy Paleobiologii i Biostratigrafii, Trudy II sessii Vses. Paleontol. obshchestva, p. 73; KHALILOV, 1962, Mikrofauna i Stratigrafiya paleogenovykh otlozhenii Azerbaydzhana, Akad. Nauk Azerbaydzhanskoy SSR, p. 40, 211, 212; DMITRIEV and KOZHEVNIKOVA, 1963, Akad. Nauk Turkmenskoy SSR, Izvestiya, Ser. Fiz.-Technich., Kimich. i Geol. Nauk, no. 2, p. 104.

Caucasinella elongata (d'Orbigny). N. K. BYKOVA, 1959, Voprosy Paleobiologii i Biostratigrafii, Trudy II sessii Vses. Paleontol. Obshchestva, p. 73; MYATLYUK, 1960, Trudy Pervogo Seminara po Mikrofaune, VNIGRI, p. 208; NIKITINA, 1962, Byull. Moskov. obshch. Ispyt. Prirody, otdel. geol., v. 37, no. 2, p. 52.

Bulimina elongata var. *elongata* d'Orbigny. SUBBOTINA, PISHVANOVA and IVANOVA, 1960, Mikrofauna SSSR, Sbornik 11, Trudy VNIGRI, vyp. 153, p. 84, pl. 5, figs. 12, 13.

Bulimina (= Caucasinella) elongata d'Orbigny. NIKITINA, 1962, Byull. Moskov. obshch. Isypt. Prirody, otdel. geol., v. 37, no 2, p. 60.

Test elongate, varying from slightly tapering throughout to tapered only in early trochospiral portion and nearly cylindrical in later portion; chambers at first trochospiral, later reducing in number of chambers per whorl to become triserial, chambers slightly inflated, of nearly equal breadth and height; sutures slightly depressed; wall calcareous, finely perforate, polished, smooth; aperture an elongate loop with narrow bordering lip, forward apertural margin somewhat overlapping base of opposite margin which is infolded and flaring to form the apertural toothplate.

Length of figured specimens, 0.50 and 0.52 mm; breadth 0.24 and 0.28 mm. Cushman and Parker state that the species ranges from 0.28 to 0.67 mm in length and from 0.14 to 0.22 mm in diameter.

Remarks: Cushman and Parker, (1937, p. 49) regard *Bulimina inconstans* Egger, from the Miocene of Bavaria, and *B. scabriuscula* Reuss, from the Belgian Pliocene, as synonymous with the present species. We have not compared the primary types of these latter species, but *B. inconstans* is a short flaring foraminifer with few, but inflated and subglobular chambers, and *B. scabriuscula* is a narrow elongate form with narrow elevated chambers. Apparently, neither has an early trochospiral coil, hence we do not regard them as synonymous.

This species also has been reported from the Miocene of the Carpathians (Ukrainian SSR) and the Caucasus of Georgian SSR and Azerbaijan SSR.

Types and Occurrence: Hypotypes (UCLA 34231-34232) from the Miocene (Tortonian) Badener Tegel, Baden, Austria; collected by W. W. Hay.

CAUCASINA SUBULATA (Cushman and Parker)

Pl. 2, figs. 10-13

Bulimina elongata d'Orbigny var. *subulata* CUSHMAN and PARKER, 1937, Cushman Lab. Foram. Res., Contr., v. 13, p. 51, pl. 7, figs. 6-7; VENGLINS'KIY, 1958, Foraminiferi Miotsenu Zakarpattya, Akad. Nauk Ukraïns'koï RSR, Inst. Geol. Korisnikh Kopalin, p. 133, pl. 28, fig. 2.

Bulimina elongata d'Orbigny var. *lappa* CUSHMAN and PARKER, 1937, Cushman Lab. Foram. Res., Contr., v. 13, p. 51, pl. 7, fig. 8; CUSHMAN and PARKER, 1947, U. S. Geol. Survey, Prof. Paper 210-D, p. 109, pl. 25, fig. 19.

Caucasina schischkinskye (Samoylova). VENGLINS'KIY, 1958 (*non* Samoylova), Foraminiferi Miotsenu Zakarpattya, Akad. Nauk Ukraïns'koï RSR, Inst. Geol. Korisnikh Kopalin, p. 33, 135, table 3, pl. 29, figs. 4-9.

Bulimina subulata Cushman and Parker. SUBBOTINA, PISHVANOVA and IVANOVA, 1960, Mikrofauna SSSR, Sbornik 11, Trudy VNIGRI, vyp. 153, p. 86, pl. 5, fig. 16, 17; VYALOV, PISHVANOVA, PETRASHKEVICH and GRISHKEVICH, 1962 Byull. Moskov. obshch. Ispyt. Prirody, otdel. geol., v. 37, no. 5, p. 71, 74, 75.

Test free, elongate, slightly flaring, base bluntly rounded, early portion in low trochospiral coil of about 3 whorls, with 6 to 7 chambers per whorl, then becoming higher spired and reduced to 3 chambers per whorl; sutures distinct, strongly depressed; wall calcareous, finely perforate, granular, surface smooth, but early chambers with one to 5 or 6 solid blunt spines, varying from relatively long spines to a mere roughened basal surface of the test, and with all gradations present between these extremes of spine development; aperture an arch at base of final chamber, extending up the face, the posterior apertural margin infolded as a flaring apertural toothplate.

Figured specimens range from 0.47 to 0.68 mm in length and 0.23 to 0.29 mm in breadth.

Remarks: Figured topotypic specimens are from the Miocene of Baden, Austria, and were compared with the holotype of *Bulimina elongata* var. *lappa* (USNM Cushman Coll. 23725) from the Miocene at Nussdorf, Vienna Basin, Austria. The two varieties were also reported to occur in the Miocene of Hungary and Egypt and the Pliocene of Italy. The Pliocene specimens of *Bulimina elongata* var. *lappa* from Attavilla, Italy (USNM Cushman Coll. 59128) were examined by us. They represent a short, broad, hirsute *Bulimina* and are not referrable to the present species or genus. Venglins'kiy (1958) referred to *C. schischkinskye* [sic] specimens from the Sarmatian of the Zakarpats'ky district (Borzhavs'ka series) which show the characteristic roughened and spiny base of the present species.

The varieties *subulata* and *lappa* were stated to occur together, the latter being shorter and heavier with shorter spines or merely roughened base, the typical *subulata* being distinctly spinose. In a large number of topotypic specimens a gradation occurs between specimens of these extremes, partly because of breakage of the spines and partly a dimorphism between the more elongate and tapering microspheric and blunter megalospheric specimens. They are regarded as identical, being merely variants within a single population.

The species figured by Brady (1884, pl. 51, fig. 1) from the North Atlantic, northwest of Ireland, as *Bulimina elongata,* and that (pl. 51, fig. 2) considered to be intermediate between *B. elongata* and *B. ovata* d'Orbigny, were regarded by Cushman (1942, p. 11) as *B. elongata* var. *subulata.* Although of similar outline and size, the Recent specimens need restudy, and refiguring in basal view in order to determine whether or not they are referrable to *Caucasina subulata* or *C. elongata*—or even to the present genus.

Caucasina subulata also has been reported from the Miocene of Rumania, Albania and the pre-Carpathians of the Ukrainian SSR.

Types and Occurrence: Topotypes (UCLA 34233-34236) of *C. subulata* (Cushman and Parker) from the Miocene (Tortonian) Badener tegel, Baden, Austria; collected by W. W. Hay. The species appears to be widespread in Sarmatian-Tortonian deposits of central Europe, but we have not seen younger specimens that we regard as conspecific.

7. *Nomina Nuda*

The following specific names have appeared in Soviet publications, but we have been unable to locate published descriptions. They are therefore regarded as *nomina nuda.*

CAUCASINA BULIMINOIDES Bogdanovich

Caucasina buliminoides NIKITINA, 1962, Byull. Mosk. Obshch. Ispyt. Prirody, otdel. geol., v. 37, no. 2, p. 52 (table), 60 (list).

Caucasina buliminoides Bogdanovich. NOSOVSKIY and SAVENKO, 1963, Doklady Akad. Nauk SSSR, v. 148, no. 5, p. 1179 (in list); DIDKOVS'KIY, 1963, Geol. Zhurnal, Akad. Nauk Ukraïns'koï RSR, v. 23,

no. 2, p. 98 (in list) Burdigalian (Miocene) of northern Caucasus.

CAUCASINA LUCERA Pishvanova

Caucasina lucera Pishvanova. VYALOV, PISHVANOVA, PETRASHKEVICH and GRISHKEVICH, 1962, Byull. Moskov. Obshch. Ispyt. Prirody, otdel. geol., v. 37, no. 5, p. 74; IVANOVA, 1962, Dopovidi Akad. Nauk Ukraïns'koï RSR, no. 4, p. 521 (in list).

This species may have been described in an unpublished dissertation from L'vov University (1960): Pishvanova, L. S., Foraminifery miotsena predkarpat'ya i ikh stratigraficheskoe znachenie: Avtoreferat. Rand. dis. L'vov, 1960.

CAUCASINA SCHISCHKINSKAYAE (Samoylova) var. DOLIELLA Ivanova, 1956

Caucasina schisckinskyae (Samoylova) var. *doliella* IVANOVA, 1956, Geol. Sbornik, L'vovskogo Geol. Obshch., no. 2-3, p. 327 *(err. cit.;* recte *C. schischkinskayae* var. *doliella).*

CAUCASINA SUZAKENSIS N. K. Bykova, 1960

Caucasina suzakensis N. K. BYKOVA, 1960, Geol. Sbornik no. 5, Trudy VNIGRI, vyp. 163, p. 315, pl. 2, A5 (*nom. nud.*, figured, not described).

8. *Nomenclatura aperta*

CAUCASINA sp. Bignot, 1962

Caucasina sp. BIGNOT, 1962, Rev. Micropaléontologie, v. 5, no. 3, p. 169, pl. 2, figs. 34-35.

Eocene (Cuisian), Cap d'Ailly, Seine Maritime, France.

CAUCASINA sp. nov. (?) Bogdanovich, 1960

Caucasina sp. nov. (?) BOGDANOVICH, 1960, Trudy VNNII, Krasnodarskiy filial, Trudy, vyp. 4, Geol. Sbornik, p. 240, pl. 3, figs. 4, 5.

Assinsky beds, middle Maykopian (upper Oligocene), Urukhskiy region, N. Osetiya, USSR.

B. Genus AEOLOMORPHELLA Loeblich and Tappan, n. gen.

Type species: *Aeolomorphella plectilis,* n. sp.

Test free, elongate, early stage in close discorbine coil, up to 6 chambers per whorl, later becoming high spired with rapid reduction in number of chambers per whorl, finally biserial; chambers broad and low in early stage, later of nearly equal breadth and height and somewhat inflated; sutures distinct, depressed; wall calcareous, finely perforate, granular; surface smooth; aperture a high loop shaped opening extending up the apertural face from its base, with posterior margin infolded to form a toothplate.

Remarks: Aeolomorphella differs from *Caucasina* in being biserial rather than triserial in the later stage.

Occurrence: Upper Cretaceous (Campanian) of northern Alaska.

AEOLOMORPHELLA PLECTILIS Loeblich and Tappan, n. sp.

Pl. 1, figs. 1-4

Aeolostreptis vitrea (Cushman and Parker). TAPPAN, 1960, Amer. Assoc. Petr. Geol., Bull., v. 44, no. 3, p. 285, 289.

Caucasina vitrea (Cushman and Parker). TAPPAN, 1962, U. S. Geol. Survey, Prof. Paper 236-C, p. 188, pl. 49, figs. 23-25.

non *Buliminella vitrea* CUSHMAN and PARKER, 1936, Cushman Lab. Foram. Research, Contr., v. 12, pt. 1, p. 7, pl. 2, figs. 4a-c.

non *Aeolostreptis vitrea* (Cushman and Parker). LOEBLICH and TAPPAN, 1957, U. S. Natl. Museum, Bull. 215, p. 227, pl. 72, fig. 20.

Test free, elongate, base bluntly rounded, early portion close coiled with 6 low chambers per whorl, later reducing to triserial and finally biserial, with chambers of nearly equal breadth and height; sutures distinct, depressed, becoming more constricted in later stages; wall calcareous, finely perforate, surface smooth; aperture an arched slit extending up the face from inner margin of final chamber, with narrow lip at the forward margin.

Length of holotype 0.26 mm; breadth 0.13 mm. Other specimens range from 0.10 to 0.28 mm in length.

Remarks: The present species was formerly regarded by us as conspecific with *Caucasina vitrea,* from the Upper Cretaceous of Mississippi, but it differs in the more elongate test, less rapid flaring, final biserial chamber arrangement, more incised sutures and chambers of nearly equal breadth and height. It differs from *Caucasina tuzkoensis,* from the Upper Cretaceous (Campanian) of central Asia (Kyzylkumy), in having a slightly flaring test instead of parallel sides, in the more incised sutures and in the more equidimensional, biserially arranged chambers.

Types and Occurrence: Holotype (UCLA 34237) and figured paratypes (UCLA 34238-34239) from the Sentinel Hill member of the Schrader Bluff formation, in bank of river at Ocean Point on the Colville River, northern Alaska; collected by C. A. Hall.

The species was previously reported (as

Caucasina vitrea) from cores in the Sentinel Hill Member of the Schrader Bluff Formation, in Sentinel Hill Core Test 1 on the west bank of the Colville River, lat. 69° 35′48″N., long. 151°28′09″W., northwest of Umiat, northern Alaska.

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COSTELLACESTA, A NEW SUBGENUS OF *LIMA* FROM THE CRETACEOUS OF THE GULF AND ATLANTIC COAST PROVINCE

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CONTENTS

		Page
	ABSTRACT	89
I.	INTRODUCTION	90
II.	ACKNOWLEDGMENTS	90
III.	BIOSTRATIGRAPHY	90
IV.	PHYLOGENY AND EVOLUTION	92
V.	THE ECOLOGY OF GIANT LIMAS	92
VI.	SYSTEMATIC DESCRIPTIONS	94
	Genus *Lima*	94
	Subgenus *Costellacesta*	95
	Lima (Costellacesta) riddlei, n. sp.	95
	Lima (Costellacesta) sayrei Stephenson	97
	Lima (Costellacesta) insolita Stephenson	99
VII.	REFERENCES CITED	99
	TABLE 1: Measurements of *Lima (Costellacesta) riddlei,* n. sp.	96
	TABLE 2: Measurements of *Lima (Costellacesta) sayrei* Stephenson	97
	TABLE 3: Measurements: Holotype of *Lima (Costellacesta) insolita* Stephenson	99
	TEXT FIGURE 1: Stratigraphic occurrence and phylogeny of *Costellacesta*	91
	TEXT FIGURE 2: Depth distribution of living giant Limas	93
	TEXT FIGURE 3: Cardinal area of *Lima (Costellacesta) riddlei,* n. sp.	96
	PLATE I	101

ABSTRACT

The new subgenus *Costellacesta* is proposed for large Maestrichtian species of *Lima* with an opisthocline shell, large lunule and byssal gape, single (posterior) auricle, a resilifer situated posterior to the beak, and ornamentation consisting of fine costellae intercalated between prominent, equally developed costae. Three species of *Costellacesta* are known and described: *L. (C.) riddlei,* n. sp., the type species (oldest; Chiwapa Sandstone Member, Mississippi), *L. (C.) sayrei* Stephenson (Corsicana Marl, Texas), and *L. (C.) insolita* Stephenson (youngest: upper Peedee Formation, North Carolina). These represent a single line of descent without significant break. Successively younger species demonstrate the following evolutionary trends: change in marginal outline, particularly an increase in concavity of the dorsoanterior margin; increase in the relative size of the lunule and byssal gape; re-

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duction in the strength of the costae and costellae; increase in number of costellae, and decrease in number of costae per unit length; possible decrease in maximum adult size.

Costellacesta is possibly ancestral to plicate Cenozoic *Limas* of the subgenus *Plicacesta* Vokes. The habitat of *Costellacesta* was probably analogous to that of living giant *Limas (Acesta, Plicacesta)*—cold, deep waters of the continental slope and abyss, rarely ranging into warm, shallow shelf environments. This might explain the uncommon occurrence of *Costellacesta* in shallow water Cretaceous deposits of the Atlantic and Gulf Coastal Plain Province. The subgenus is known only from this area, and probably represents an endemic group.

I. Introduction

Lima is a common element of Gulf and Atlantic Coast Cretaceous pelecypod assemblages. Individual species are widely distributed and are represented in a variety of lithologies, rendering them potentially important in biostratigraphic zonation and correlation. The American species of *Lima* are divisible into several distinct lineages, some of which are treated as sections or subgenera by many workers. One of the most unusual Cretaceous lineages, and one which appears to be endemic to the Gulf and Atlantic Coast Province, is the group of giant *Lima* comprising a new subgenus, *Costellacesta* Kauffman. This lineage is possibly ancestral to the Cenozoic and Recent subgenus *Plicacesta* Vokes (1963).

Costellacesta is characterized by its large size, inequilateral (opisthocline) shell, single (posterior) auricle, large lunule and byssal gape, slightly oblique resilifer situated posterior to the beaks, and by the surface ornamentation, which consists of narrow, sparsely fluted costae and numerous, delicate, intercalated costellae. Unlike many other Cretaceous *Lima,* species of *L. (Costellacesta)* are rare and geographically restricted; few complete specimens are known. Cenozoic and Recent giant *Lima* of the subgenera *Plicacesta* and *Acesta* are similarly restricted.

Three species of *Costellacesta* are known from Upper Cretaceous sediments of the Atlantic and Gulf Coast Province. These are, from oldest to youngest: *Lima (Costellacesta) riddlei* Kauffman, n. sp. (Chiwapa Member, Ripley Formation, Mississippi), *L. (C.) sayrei* Stephenson (Corsicana Marl, Navarro Group, Texas), and *L. (C.) insolita* Stephenson (Upper Peedee Formation, Owl Creek - Providence - Prairie Bluff equivalent, North Carolina). These species occur in successive stratigraphic units, without overlapping ranges, and probably represent a continuous evolutionary sequence. Known species of *Lima (Costellacesta)* are exclusively Maestrichtian in age, and occur only in the upper half of the *Exogyra costata* zone (see Sohl, 1960, fig. 3).

II. Acknowledgments

Specimens of *Lima (Costellacesta) riddlei,* n. sp., the type species, were collected and donated to the Smithsonian Institution by Mr. W. C. Riddle of Memphis, Tennessee, as part of a program undertaken by the Mid-South Earth Science Club to provide the Institution with research material. To Mr. Riddle and his associates I offer my sincere thanks. Drs. Harold E. Vokes of Tulane University, A. Lee McAlester of Yale University, John Pojeta, Jr., and Norman F. Sohl of the U. S. Geological Survey reviewed the manuscript and offered valuable criticism. Dr. Sohl was also instrumental in locating specimens and provided valuable assistance in stratigraphic interpretation. Drawings are by Mr. L. B. Isham and Mr. L. R. Purnell, and photography by Mr. Jack Scott, all of the U. S. National Museum.

III. Biostratigraphy

The three known species of *Lima (Costellacesta)* occur at widely scattered localities; no two species have been found in the same area. Nevertheless, the stratigraphic relationships between the species are well established (fig. 1). The oldest form, *L. (C.) riddlei,* n. sp., occurs exclusively in the Chiwapa Sandstone Member of the Ripley Formation (Mellen, 1958; equivalent to the Keownville Limestone Member of Sohl, 1960, p. 18, fig. 3) near Ingomar and Pontotoc, Mississippi. The youngest member of the lineage, *L. (C.) insolita* Stephenson occurs only in the upper part of the Peedee Formation at the New Rocky Point quarries, Pender County, North Carolina (upper part of the *Exogyra costata* zone, Late Maestrichtian: Stephenson, 1927, p. 13). Here it is associated with a fauna of Owl Creek - Prairie Bluff - Providence age (Stephenson, 1927, Sohl, oral communica-

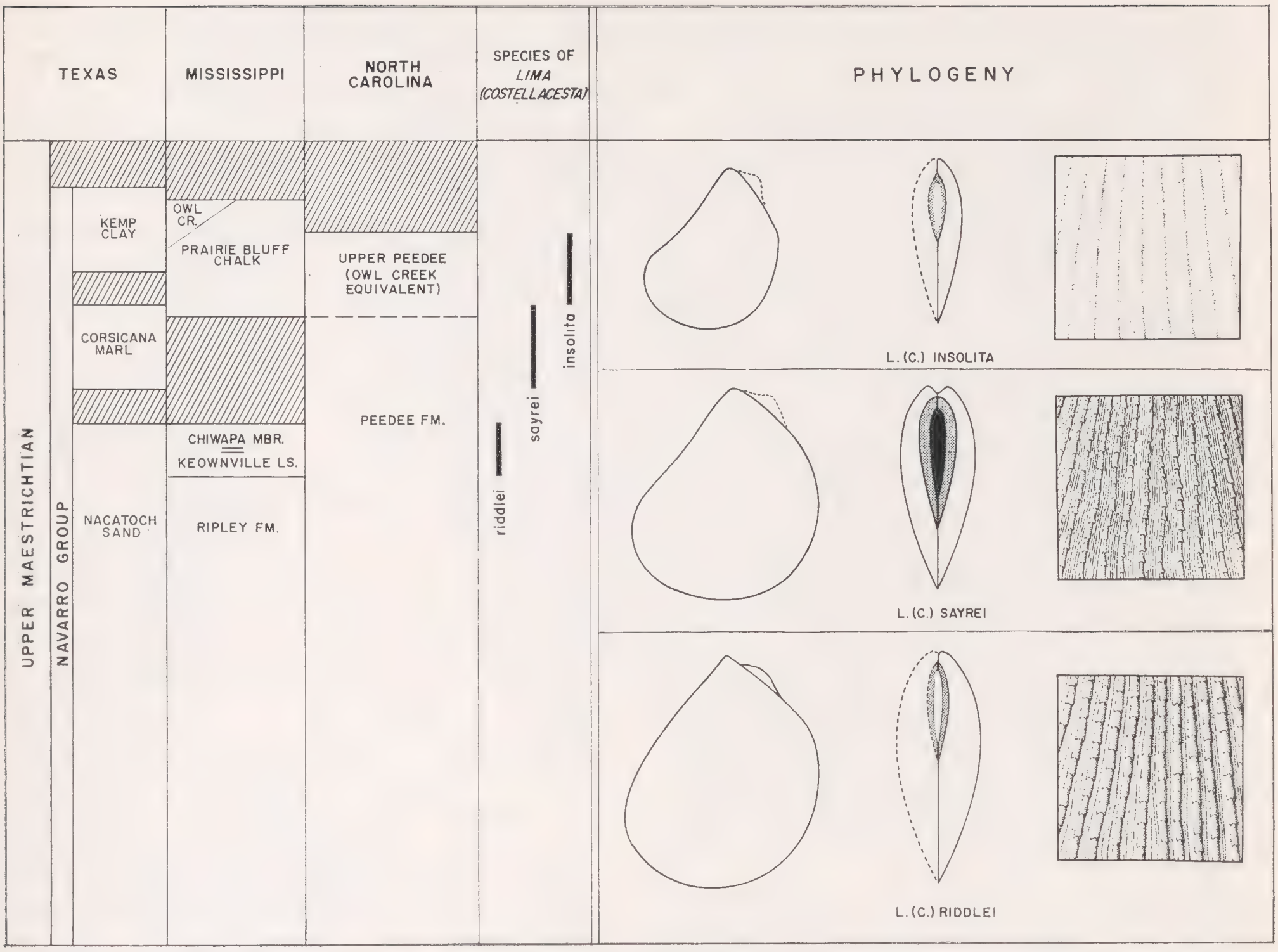

Figure 1—Stratigraphic occurrence, and phylogeny of *Costellacesta,* showing change in shape, decrease in overall size, variation in size of the lunule and byssal gape, and change in ornamentation on progressively younger species of the subgenus. Byssal gape black where definitely known, otherwise approximated by blank area in lunule. Drawings for *L. (C.) riddlei* based on holotype (USNM 132632), for *L. (C.) sayrei* on paratype (USNM 132636), and for *L. (C.) insolita* on holotype (USNM 73431). Outlines reduced ¼; ornamentation approximately X ½.

tion, 1964). Near Ingomar and Pontotoc the Prairie Bluff Chalk disconformably overlies the Chiwapa Sandstone Member of the Ripley, and although *L. (C.) insolita* does not occur here, its age relationship to *L. (C.) riddlei,* n. sp., is clearly established.

The relative stratigraphic position of *L. (C.) sayrei* from the Corsicana Marl of Texas is not as clearly defined. The Corsicana contains a fauna considered to be transitional between those of the Chiwapa Member and Prairie Bluff Chalk. In addition, there is a certain amount of faunal overlap between the Corsicana and each of these units. As a whole, the Corsicana fauna is not duplicated on the eastern Gulf Coast, however, suggesting that no lithologic equivalent occurs in this area. The Corsicana probably occupies a time span represented on the eastern Gulf Coast by a widespread disconformity between Owl Creek - Prairie Bluff strata and those of the Chiwapa Sandstone Member of the Ripley (Sohl, 1960, fig. 3). This disconformity was recognized and widely traced by Stephenson and Munroe (1937), p. 806), and is present at Ingomar and Pontotoc (Sohl, oral communication, 1964). *Lima (Costellacesta) sayrei* Stephenson therefore appears to lie stratigraphically between *L. (C.) riddlei,* n. sp., and *L. (C.) insolita* Stephenson. No species of *Costellacesta* are known to have overlapping ranges, but they are too rare to be considered important stratigraphic indices.

The subgenus *Costellacesta* is known only from Maestrichtian deposits of the Gulf and Atlantic Coast Province (fig. 1). Its range lies in the upper part of the *Exogyra costata* zone, and is approximately equivalent to the range zone of *Turritella bilira* Stephenson (Chiwapa through Owl Creek: Sohl, 1960, fig. 3. Range defined by solid and dashed

lines now definitely established; Sohl, 1964, oral communication).

IV. Phylogeny and Evolution

The *Costellacesta* lineage appears abruptly in the American Maestrichtian, and no ancestral stock is known. *Costellacesta* may have stemmed from some foreign lineage introduced in the Gulf and Atlantic Coast Province as a fully differentiated group, but a search of the principal foreign literature has not revealed any members of the subgenus, or an obvious ancestral group. Present evidence indicates that the lineage is probably endemic to this area.

The rarity of *Costellacesta* in shallow water Cretaceous Coastal Plain sediments is possibly explained by analogy with the habitats of living giant *Limas*. Vokes (1963a) has shown that living species of *Acesta* and *Plicacesta,* which are structurally similar to *Costellacesta* (pl. 1, fig. 2) are found predominantly in deep waters of the outer continental shelf, continental slope, and abyss (fig. 2). Only one species is found in less than 300 feet of water and this species is rare at this depth. It is reasonable to assume that species of *Costellacesta* were similarly distributed. If so, the ancestors and early representatives of the subgenus, and perhaps most species of the group, would thus be preserved in deep water Cretaceous sediments not presently exposed on the emergent portion of the continent. The few Cretaceous species that ranged into shallow sublittoral waters are the only ones found today in the inner shelf deposits of the Atlantic and Gulf Coastal Plain.

Although the number of specimens available for study is limited, the three known species of *Costellacesta* seem to form an evolving lineage in which some general evolutionary trends can be noted (fig. 1). Notably among these is the increase in number, but decrease in relative size and strength of the costellae in progressively younger species. The oldest known species, *L. (C.) riddlei,* n. sp., has 1 to 3 prominent fluted costellae in interspaces between adjacent costae; the middle member of the lineage, *L. (C.) sayrei* has 3 to 6 smaller, smooth costellae per interspace. On *L. (C.) insolita* the costellae are even narrower and fainter, and are visible only on parts of the shell where the ornament is coarsest. Possibly, this reflects a trend toward elimination of the costellae in the lineage. Unfortunately, the only known specimen of *L. (C.) insolita* is worn and does not permit accurate determination of the number and total extent of its costellae.

The costae exhibit additional changes through time, becoming narrower, less prominent, less numerous, and more widely spaced in progressively younger species (fig. 1). The apparent decrease in size of the adult shell, and variation in size of the lunule through time may be additional evolutionary trends, but this cannot be substantiated without more material.

The reduction in size and partial loss of costellae in the youngest member of the group, coupled with the retention of the primary radiating elements of the ornamentation (costae), gives rise to a form closely resembling species of the subgenus *Plicacesta,* known only from the Cenozoic and Recent (Vokes, 1963a). Species of *Plicacesta* lack costellae and have plicae rather than costae. This suggests close relationship or possible ancestry of *Costellacesta* to *Plicacesta.* Additional evidence for the ancestry of *Plicacesta* may be provided by future studies of certain large, coarsely plicate, Indian and European Cretaceous limids, such as *Lima ("Acesta") obliquistriata* (Forbes) (India), and *L. dujardini* Deshayes or *L. marrotiana* d'Orbigny (France). These species resemble *Plicacesta* in gross shell morphology, and are contemporary with and older than *Costellacesta.* They may represent an extension of *Plicacesta* into the Cretaceous, or may simply be coarsely ribbed *Plagiostoma.* Unfortunately, certain critical characters of these plicate Cretaceous species, such as the position and nature of the resilifer, and presence or absence of an anterior auricle, are not yet known. Subgeneric relationships cannot be determined without this knowledge.

V. The Ecology of Giant Limas

Ecologic data for living species of giant *Lima* (subgenera *Acesta, Plicacesta*) have recently been assembled by H. E. Vokes (1963a, b). The following comments are drawn from these and other works on Recent pelecypods.

The giant *Limas* have wide geographic distribution, occurring from the latitudes of

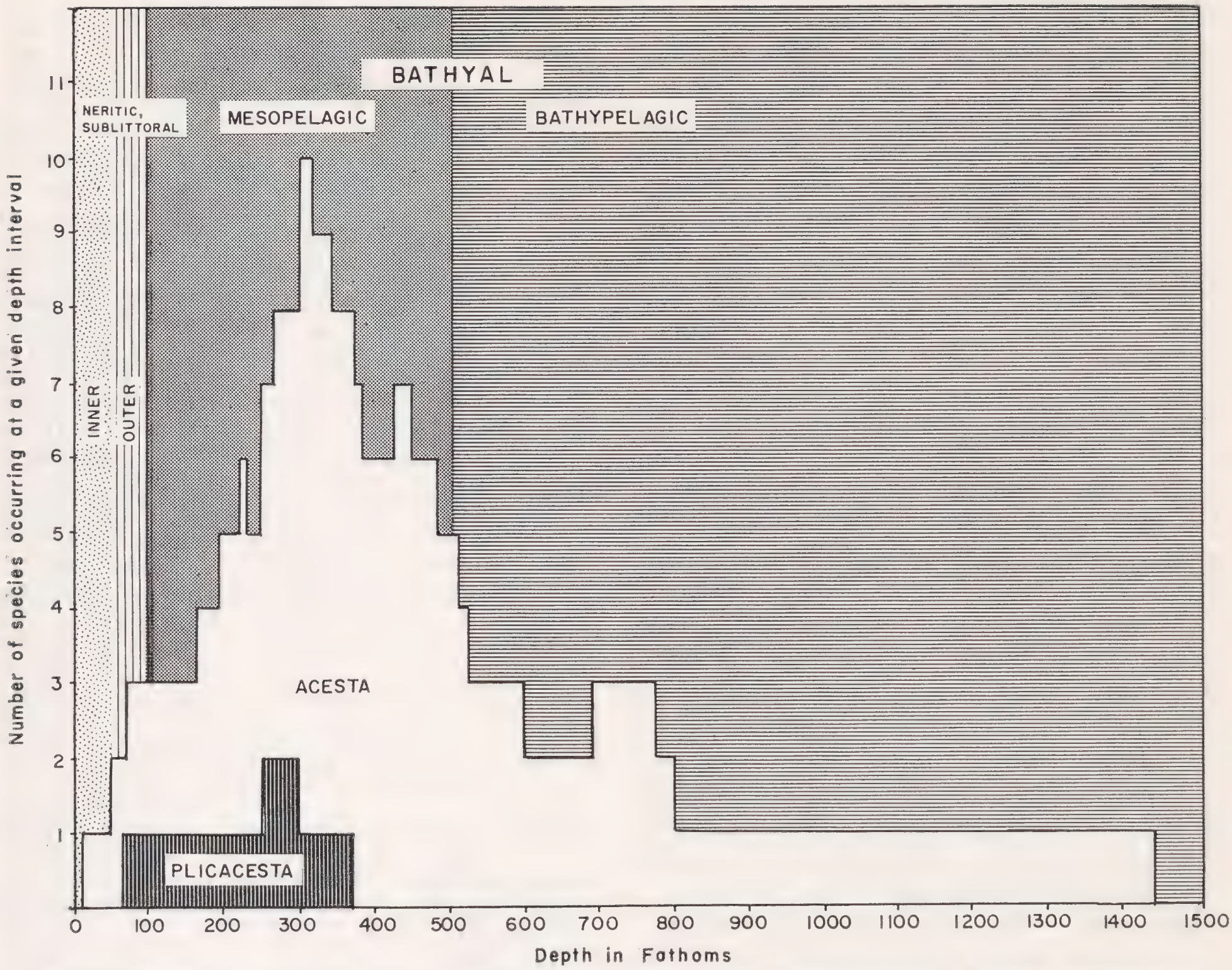

Figure 2—Depth distribution of living giant *Limas* (subgenera *Acesta, Plicacesta*). Data from Vokes (1963a, b).

Norway, Iceland, and Greenland [*L. (Acesta) excavata* (Fabricius)] south of *Patagonia* [*L. (A.) patagonica* Dall]. They are most common in the tropical and warm temperate regions of the Indo-Pacific, especially in the Philippines, East Indies (Sumatra and Borneo), and Japanese Islands. *Plicacesta* is unknown outside the Indo-Pacific, while *Acesta* has two Atlantic representatives. The Cretaceous subgenus *Costellacesta,* however, occurs exclusively in the Atlantic Province, and is the only large coarsely ribbed group of *Limas* with a posterior resilifer known from this area. It may have occupied an ecologic niche in the Atlantic during the Cretaceous similar to that presently occupied by *Plicacesta* in the Pacific.

Most species of *Acesta* and *Plicacesta* inhabit deep water of the outer continental shelf and continental slope (fig. 2). Vokes cited a bathymetric range of 16 to 1450 fathoms (96 to 8700 feet) and an average depth occurrence of 336.4 fathoms (2018.4 feet) for all living species of *Acesta* except *L. (A.)* angolensis Adam and Knudson, which occurs from 400 to 500 meters depth off Angola. Only one species, *L. (A.) goliath* Sowerby occurs uncommonly in water shallower than 300 feet. The two living species of *Plicacesta* have a combined bathymetric range of 337 to 2194 feet; the average depth for *L. (P.) smithi* Sowerby is 1265 feet, and for *L. (P.) sphoni* Hertlein 1650 feet. Since dead shells were most commonly dredged in all samples analyzed, and living specimens are not usually differentiated in dredge records, these depths are at best an approximation of the living range of the various species. However, they conclusively show a deep water habitat preference in the giant *Limas* (fig. 2).

Available temperature records for stations from which *Acesta* was taken show an average water temperature of 48.4° F. (Range 35-59.2° F.). Eliminating the warm water form, *L. (A.) rathbuni,* the average habitat temperature for all other species is 45.7° F. (Vokes, 1963a, p. 85). In some species,

depth distribution is controlled rigidly by water temperature (Vokes, 1963a, p. 80). Temperature may be the primary control on distribution in most species, though this remains to be tested. *Costellacesta* occurs with what have been considered warm, shallow water faunas but it is rare in these assemblages, as are modern giant *Limas*, and was probably more widely distributed in cooler, deeper waters during the Upper Cretaceous.

Bottom sediment was recorded from 33 stations yielding species of *Acesta.* Vokes' analysis of these data (p. 85) shows a strong preference for mud, or fine sand and mud bottoms (color predominantly green; rarely gray, blue) (24 localities). Species of *Acesta* are more rarely found associated with sand (4 occurrences), *Globigerina* ooze, ooze and sand, shell and coral bottom, rock and shell bottom, and on stones (1 occurrence each). Species of *Costellacesta* are found associated with chalky marl *(sayrei),* fine argillaceous sand *(insolita)* and chalky sandstone to arenaceous chalk *(riddlei).* These sediments are well within the range of those inhabited by *Acesta* at present.

Species of *Costellacesta* probably had habitat requirements similar to those of living giant *Limas.* This would account for the rarity in the shallow shelf sediments that characterize the Cretaceous of the Atlantic and Gulf Coastal Plain. As today, rare Cretaceous species lived on the shallow portion of the continental shelf in warmer waters; *L. (C.) riddlei, L. (C.) sayrei,* and *L. (C.) insolita* represent this shallow water element of *Costellacesta.* The preservation of complete fragile shells belonging to the known Cretaceous species probably indicates they lived near their burial site, and were not transported far after death.

Most species of *Lima* are sessile forms, attaching by byssal threads to rocks and other hard objects. Some build elaborate nests of byssal threads in order to protect their nonretractile mantle tentacles from predators. Vokes (1963a) records *L. (A.) excavata* as having been found attached by a byssus; the attachment habits of other living giant *Limas* are unknown. Many species of *Lima,* including a number of those which normally attach, possess the added ability to swim, and lie free on the bottom when not swimming. Yonge (1958, p. 171) has described the swimming:

"A swimming *Lima* is a most charming sight. Progress is made with a series of rather languid movements with each of which the long fringe of tentacles slowly rises and then gently descends around the white shell."

Although any individual swimming incident in *Lima* is short, the animal is capable of moving a considerable distance during its lifetime as long as it remains unattached. Further, it has the ability, as an adult, to be environment selective, a distinct asset to the survival potential of its offspring. Thus the individual, and its larvae, are commonly more rapidly and widely distributed than in wholly sessile pelecypods or vagrant benthonic forms, an important consideration for the paleontologist employing *Lima* in correlation.

VI. Systematic Descriptions

Family Limidae

Genus Lima Bruguiere, 1797

Lima Bruguiere, 1797, Tabl. Encycl. Meth., Vers Coq., 2, p. 206. (Valid according to International Code of Zoological Nomenclature 1961, Art. 16, a, vii; see discussion of Vokes, 1963a, p. 75, 76).
Lima Bruguiere. Cuvier, 1798, Tabl. Elem., p. 421.
Lima Bruguiere. Lamarck, 1799, Mem. Soc. d'Hist. Nat. de Paris, 1, p. 88.
Mantellum Roeding, 1798, Mus. Bolt., p. 160.
Radula Klein. Mörch, 1853, Cat. Conch. Yoldi, 2, p. 57.
Radula Klein. Adams and Adams, 1858, Genera of Recent Mollusca, 2, p. 556, 557.
Lima Bruguiere. H. E. Vokes, 1963, Tulane Stud. Geol., 1, No. 2, p. 75, 76.

Type species: *Ostrea lima* Linnaeus=*Lima squamosa* Lamarck; by subsequent tautonomy (Lamarck, 1801).

Diagnosis: Shell thin, small to moderately large; outline ovate, obliquely subovate, or subquadrate; predominantly equivalve, slightly to greatly inequilateral, with one (posterior) or two small, unequally developed auricles. Anterior byssal gape small to large; posterior gape uncommonly developed. Lunule commonly present. Valves nearly smooth, with incised radiating lines, costellate, costate, or finely plicate. Commissure smooth to crenulate. Hinge line short; cardinal area consisting of central triangular resilifer, erect to oblique, beneath or posterior to beak, bounded laterally by flat cardinal plates for ligament attachment. Pallial line entire, faint. Monomyarian, posterior adductor muscle scar large, in some cases complex, irregular, commonly situated posterocentrally.

Subgenus COSTELLACESTA Kauffman, n. subgen.

Type species: *Lima (Costellacesta) riddlei* Kauffman, n. sp.

Diagnosis: Large, equivalve, moderately inequilateral opisthocline, slightly prosogyre to pisthogyre. Outline obliquely subovate, with long straight dorsoanterior edge. Lunule large, well defined. Byssal gape lanceolate, large, dorsoanterior to mid-anterior. Posterior auricle small, dorsoposteriorly situated, separated from main body of shell by well defined auricular sulcus. No anterior auricle. Surface covered by prominent, evenly developed, widely and subequally spaced costae, smooth to finely fluted or spinose at intersection with major growth lines. Adult costae narrower than interspaces between them, 1-6 fine, evenly spaced, subequally developed costellae commonly intercalated between adjacent costae. Commissure flat to very faintly undulating. Hinge line short, straight, situated mainly below and posterior to beaks. Resilifer slightly oblique to hinge line, triangular, moderately large, situated just posterior to beak. Lateral cardinal plates flat, triangular, unequal. Pallial line and musculature unknown. Shell thin.

Remarks: Costellacesta is distinct from the subgenus *Acesta* Adams and Adams in lacking an anterior auricle, having a more projecting, beak and narrower umbone, in its larger lunule and byssal gape, more prominent auricular sulcus, and in having prominent radial sculpture, consisting of narrow costae and intercalated costellae, covering the entire valve. *Plicacesta* is even more similar to *Costellacesta,* but can be distinguished by its radial plicae of only one size which involve the entire thickness of the shell and are reflected internally. In addition, the plicae are broader than the interspaces between them, and are coarser, broader, and more crowded than those on species of *Costellacesta.* Finally, *Plicacesta* appears to have at least a remnant anterior auricle, a more oblique resilifer, and commonly a smaller lunule and byssal gape than found on *Costellacesta.* The subgenus *Costellacesta* is uncommon, and is known only from the Maestrichtian deposits of the Gulf and Atlantic Coast Province, from Texas to North Carolina.

Many Jurassic species of *Lima* attain a size equivalent to that of *Costellacesta, Acesta,* and *Plicacesta.* Most of these belong to the subgenus *Plagiostoma* and are not closely comparable. One group, however, the subgenus *Regalilima* Cox, has many morphologic features suggestive of the giant Cretaceous, Cenozoic, and Recent *Limas*, in particular the valve outline, single (posterior) auricle, large lunule and byssal gape. *Regalilima* is distinct in having radial sculpture consisting of incised lines, and a resilifer which appears to lie directly beneath the beak. Nevertheless the similarities are so striking that it is not difficult to envision the *Acesta - Costellacesta - Plicacesta* complex as having arisen from such a group.

The morphologic criteria and the magnitude of structural differences which distinguish *Costellacesta* from other subgenera of *Lima* are equivalent to those which separate far better known limid subgenera such as *Acesta* and *Plicacesta.* These well studied subgenera probably arose from a common Mesozoic stock, and are known to have evolved as distinct lineages through the Cenozoic. *Costellacesta* appears to have had a similar history. The restricted number of specimens available for study, and lack of knowledge concerning its ancestors and descendants should not detract from the recognition of *Costellacesta* as a distinct subgenus.

LIMA (COSTELLACESTA) RIDDLEI, n. sp.

Pl. I, figs. 3, 4, 6

Material: A single, nearly complete, large right valve showing the hinge characters; two moderately well preserved, medium size valves (right and left); a large shell fragment.

Description: Summary of measurements presented in Table 1. Shell attaining large size, equivalve, height greater than length; moderately inequilateral, opisthocline, opisthogyre. Outline subtriangular to trigonal-subovate; valves oblique (pl. 1, fig. 4). Posterior and ventral margins moderately and subevenly rounded; anteroventral margin more narrowly rounded; anterior margin straight to very slightly curved (convex outward), steeply inclined to hinge axis. Valves moderately convex dorsocentrally, on umbone; ventral, ventrolateral, posterior flanks slightly convex, gradually flattening toward margin. Anterior slope, especially dorsal half, gently convex centrally, abruptly truncated and sharply incurved at edge of lunule. Lunule poorly known, apparently long, moderately broad, excavated, and largely filled with a lanceolate byssal gape equal to one-third or one-half of the anterior margin. Rim of lunule at perimeter of gape apparently narrow.

Beak pointed, somewhat projecting, apical angle slightly greater than 90° (pl. 1, fig. 4); umbone poorly defined, moderately convex, costate. Umbonal midline straight, slightly opisthogyre. Beak situated about

five-eights the length from the anterior margin. Anterior auricle not developed. Posterior auricle small (pl. 1, fig. 4), outline subcrescentic, with straight dorsal margin, gently rounded posterior margin. Auricle flat to slightly convex, separated from main body of valve by narrow, moderately deep, well defined auricular sulcus.

Entire surface of valve covered with evenly spaced, moderate size, subequally developed, straight, primary costae (pl. 1, fig. 3, 4) with steep flanks and flat to gently rounded crests over early part of valve, becoming fluted and more narrowly rounded ventrally and laterally near valve margins. Fluting produced at intersections with coarsest growth lines. Costae slightly more crowded posteriorly and centrally than anteriorly. Costal interspaces shallow, flat-based, slightly to moderately broader than costae on ventral two-thirds of valve, narrow dorsally. 1 to 3 costellae intercalcated in interspaces between adjacent costae on ventral one-half to two-thirds of valve (pl. 1, fig. 3); 2 or 3 costellae per interspace most common near margin. First formed costellae appear about one-third the height below the dorsal margin; second and third costellae for each interspace appear at or ventral to midvalve, expanding slightly toward margins. Ornament of auricle similar, but with more crowded costae and fewer costellae. Commissure flat to gently undulating at points where costae intersect margin of valve.

Concentric ornamentation on dorsal three-quarters of valve consisting of very faint, fine, crowded growth lines. Growth lines coarser on ventral one-quarter of valve, at widely spaced intervals crowded and prominent, associated with small concentric constrictions, particularly prominent near anterior and posterior margins.

Hinge line short, straight to slightly curved. Cardinal area broad, short, thick, situated below and posterior to beaks, consisting of a central triangular resilifer, posterior to beak and somewhat oblique to hinge axis, bounded by flat, subtriangular, lateral cardinal plates (fig. 3). Muscle scar, pallial line unknown. Shell thin, smooth internally.

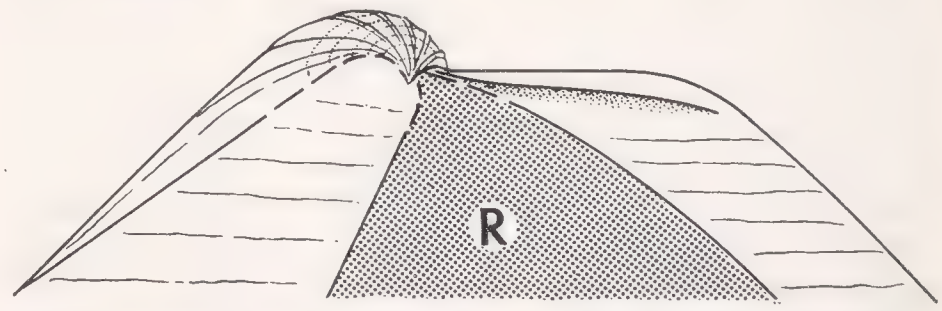

Figure 3—Cardinal area of *Lima (Costellacesta) riddlei* Kauffman, n. sp. showing position of resilifer (R) posterior to beak. Beak and apex of resilifer reconstructed (dashed lines). Ventral margin of cardinal area buried in matrix. Holotype, USNM 132632; enlarged X 2½.

Remarks: Lima (Costellacesta) riddlei, n. sp., is distinct from *L. (C.) sayrei* Stephenson, the most closely comparable Cretaceous species, in having a subtriangular outline, a straight to slightly curved (convex outward)

TABLE 1
MEASUREMENTS OF *LIMA (COSTELLACESTA) RIDDLEI,* N. SP.
(E = ESTIMATED ON BASIS OF RECONSTRUCTION OF VALVE)

	Holotype USNM 132632	Paratype USNM 132633	Paratype USNM 132634
Height (mm)	91.5	75 E	59 E
Length (mm)	75.5	62.3	
Width (mm)	17.4	11.2	11
Distance, anterior margin to beak, along line parallel to hinge axis (mm)	41.4	38.4	
Length of posterior auricle (mm)	18		
Height of posterior auricle (mm)	11		
Angle of inclination: entire valve	95°	105° E	
Angle of inclination: beak, umbo	94°	98° E	
Angle between hinge axis and dorso anterior margin	48°	55° E	
Angle between hinge axis and auricular sulcus	37°		
Auricular angle (between posterior, dorsal margins)	36°		
Number of costae 10 mm below beak	41	36	38
Number of costae in 20 mm length, 20 mm below beak	21	19	21
Terminal number of costae	45	41	
Number of costellae in 20 mm length, 20 mm below beak	5	23	25
Terminal number of costellae	78	54 E	
Length of hinge line (mm)	22.9		
Angle of inclination of resilifer to hinge axis	81°		

dorsoanterior margin, a straighter midline, slightly more convex valves, a smaller, narrower lunule and byssal gape, fewer but coarser costellae per interspace, arising at a later developmental stage, and straighter more numerous, more crowded, and more prominent costae (compare pl. I, figs. 3, 4 with figs. 7, 9). *Lima (Costellacesta) insolita* Stephenson is smaller, having faint, greatly reduced costellae, and smooth, low, rounded, more widely spaced costae.

Lima (Costellacesta) riddlei is chosen as the type species of *Costellacesta* because it is the best known of the three species placed in this group; the holotype exhibits most of the essential characters of the subgenus, including the cardinal area. The species is named in honor of Mr. William C. Riddle of Memphis, Tennessee, who collected and contributed the types, and many other specimens of Cretaceous mollusks, to the study collections of the Smithsonian Institution.

Stratigraphic and geographic position: The holotype and two paratypes were collected from the Chiwapa Sandstone Member (= Keownville Limestone Member) of the Ripley Formation near Ingomar, Union County, Mississippi. The third paratype (USNM 132634) comes from USGS locality 25418 (locality 38 of Sohl, 1960, p. 36, 37), from roadcuts on new Mississippi State Route 6, 3.5 miles east of Pontotoc, NE1/4 SW1/4 sec. 35, T. 9 S., R. 3 E., Pontotoc County, Mississippi, in the Chiwapa Limestone Member.

Types: Holotype, a nearly complete right valve, USNM 132632. Largest paratype, a medium size right valve, USNM 132633; a smaller paratype, about two-thirds of a crushed left valve, USNM 132634; a paratype, a shell fragment sectioned to observe thickness and inner valve surface, USNM 132635.

Lima (Costellacesta) sayrei Stephenson
(Pl. I, figs. 5, 7, 9)

Lima ? sayrei Stephenson, 1941, The larger invertebrate fossils of the Navarro Group of Texas: Univ. Texas Publ. no. 4101, p. 146, 147, pl. 23, figs. 12, 13.

Material: The primary types of the species: 2 nearly complete, articulated pairs of adult valves (USNM 76476, 132636); 1 fragment of a large valve (USNM 76477).

Description: Summary of measurements presented in Table 2. Shell large, thin, equivalve, moderately inequilateral, opisthocline. Outline subovate; dorsal margin apparently short, straight over posterior auricle; dorsoanterior margin long, straight to slightly concave, moderately inclined to hinge axis; ventroanterior, ventral, posterior margins moderately and unevenly rounded greatest curvature ventroanteriorly, decreasing pos-

Table 2

MEASUREMENTS OF *LIMA (COSTELLACESTA) SAYREI* STEPHENSON
(L = MEASURED ON LEFT VALVE; R = MEASURED ON RIGHT VALVE;
C = MEASURED ON BOTH ARTICULATED VALVES AND VALVES SAME;
E = ESTIMATED)

	Holotype USNM 76476	Paratype USNM 76477
Height (mm)	95 C	84 C E
Length (mm)	84 C	79.2 C
Width (mm)	16.6 R	14.9 R
	32.6 C	30 L
Distance, beak to anterior margin, along line parallel to hinge axis (mm)	32.5 C	49.2 L E
Length of lunule, along margin (mm)	55.5 C	54.6 C
Width of lunule; maximum (mm)	14.4 C	15.7 C
Length of byssal gape, along margin (mm)		40.3 C E
Width of Byssal gape; maximum (mm)		6.1 C
Angle of inclination, entire valve	110 C	108 C
Angle of inclination, beak and umbone	88 C E	86 C E
Angle between hinge axis and dorsoanterior margin	40 C	42 L
Angle between hinge axis and dorsoposterior margin	57 C	52 L
Number of costae 10 mm below beak	29 L	
Number of costae in 20 mm length, 20 mm below beak	14 L	19 L
Total number of costae at margin	35 L	39 L
Number of costellae in 20 mm length, 20 mm below beak	30 L	44 L
Total number of costellae at margin	130 L	165 L

teriorly; margin concave and notched dorsoposteriorly beneath auricle. Central dorsal parts of valve slightly to moderately convex, ventral, ventrolateral, posterior flanks slightly flattened, dorsoanterior flanks steeply inclined into lunule. Lunule poorly preserved on all specimens (pl. 1, fig. 5); lanceolate, long, occupying dorsal one-half of anterior margin, excavated, moderately deep, apparently sharply defined and partially over hung by abruptly truncated dorsoanterior margin. Anterior byssal gape long, moderately narrow, lanceolate (pl. 1, fig. 5); commissure slightly upturned around gape, flat to very faintly undulating over remainder of valve.

Beaks not known. Umbone slightly to moderately convex, apparently erect to slightly prosogyre. Anterior auricle absent; anterior edge of cardinal area rounded, slightly projecting and incurved at dorsal extremity of byssal gape, similar to illustrated specimen of *L. (Plicacesta) smithi* (pl. 1, fig. 1). Posterior auricle small, flat, incompletely known on both specimens (see Stephenson, 1941, pl. 23, fig. 12) apparently straight dorsally, rounded posteriorly, with distinct ornamentation. Posterior auricular sulcus narrow, moderately deep, well defined, an enlarged and much deepened interspace between costae. Hinge line not preserved, assumed similar to *L. (C.) riddlei,* n. sp. Pallial line, musculature, unknown.

Ornamentation consisting of 34 to 38 simple primary costae separated by 3 to 6 fine intercalated costellae per interspace (pl. 1, fig. 7). Costae prominent, subevenly spaced, equally developed, narrow, steep-sided, with rounded crests, originating on early part of umbone, their trace straight to slightly curved over most of shell, gently sinuous ventrally and ventrolaterally at intersections with major concentric elements. Costae slightly more crowded posteriorly than anteriorly; 2 to 3 costae closely crowded on inturned edges of lunule and on steep part of dorsoposterior flank descending into auricular sulcus. Costae fluted to subspinose at somewhat regular intervals where intersected by major growth lines (pl. 1, fig. 7); 4-10 flutes per centimeter, best developed ventrally. Costellae fine, thread-like, evenly spaced and equally developed in broad flat interspaces between costae; straight to slightly sinuous, beaded due to irregularities produced at intersections with majority of growth lines (pl. 1, fig. 7). 1 to 2 costellae present between each pair of costae on earliest part of umbone preserved; number increasing by intercalation throughout growth of shell, with 5 to 6 commonly found in interspaces near margin of adult shell (pl. 1, fig. 7, 9). Concentric ornament consisting of faint to well defined but small, crowded growth lines over entire shell, and 2 to 3 scattered, narrow zones of moderate to coarse growth lines, and more rarely lamellae, near margin (outer 1 inch or less).

Ornamentation of posterior auricle distinct, consisting of crowded, coarsely fluted costae like those on main body of shell, separated by equally wide or narrower, rounded interspaces rarely bearing a single, intercalated, fluted costella.

Remarks: Lima (Costellacesta) sayrei Stephenson is the largest and most ornate species of the lineage. It is known only from Stephenson's 3 type specimens. Although he partially excavated them, Stephenson did not note the lunule with its large byssal gape. Consequently, he reversed anterior and posterior throughout his description, considering the left valve the right, and the auricle as being anterior. Comparison of the species of *Costellacesta* with the similar, living, *Lima (Plicacesta) smithi* (pl. I, figs. 1, 2) clearly shows that the major byssal gape is dorsoanterior and situated in a prominent lunule, the anterior auricle is absent, and the valves are opisthocline. Anterior and posterior are determined on *L. (P.) smithi* by the resilifer (oblique and posterior to the beak) and the well developed posterior adductor muscle scar. A parallel orientation in *Costellacesta* is determined by the position of the lunule and byssal gape on all species, and by the position of the resilifer in *L. (C.) riddlei,* n. sp.

The distinction between *L. (C.) sayrei* and *L. (C.) riddlei* have been discussed under the "Remarks" section for the latter species. *L. (C.) sayrei* is distinguished from *L. (C.) insolita* Stephenson by its larger size, more rounded outline, more prominent and slightly more numerous fluted costae, and especially by its more numerous, more extensive beaded costellae. *L. (C.) sayrei* also appears to have a larger byssal gape, and better defined lunule. Stephenson illustrated the holotype (1941, pl. 23, fig. 12).

Stratigraphic and geographic distribution: Lima (Costellacesta) sayrei is known only from the Corsicana Marl, Navarro Group, at U.S.G.S. locality 15621, in a ravine east of Medio Creek, 0.8 mile south of Castroville road, near Castroville, Texas; at U.S.G.S. locality 15622, from a bluff on Medio Creek about 0.8 mile "below" (south of) Castroville road; and from 6 miles east of Castroville, Texas (Texas Bureau 53; locality of holotype).

Types: Holotype, the largest set of relatively complete articulated valves USNM 76476. Paratypes, a well preserved set of articulated valves (U.S.G.S. loc. 15621), USNM 132636 (pl. I, figs. 5,9) (formerly

a part of USNM 76477, unfigured paratype lot); a shell fragment showing the ornament (USGS loc. 15621, USNM 76477).

Lima (Costellacesta) insolita Stephenson

Pl. I, figs, 8, 10

Lima insolita Stephenson, 1927, Additions to the Upper Cretaceous Invertebrate faunas of the Carolinas: Proc. U. S. Natl. Mus., v. 72, art. 10, p. 13, pl. 5, fig. 10.

Material: A single, nearly complete, worn adult left valve, the holotype (USNM 73431).

Description: Summary of measurements presented in Table 3. Shell moderately large, thin, presumably equivalve; inequilateral, moderately opisthocline; height greater than length. Outline subovate, with long, slightly concave, dorsoanterior margin. Ventroanterior margin strongly curved; ventral, posterior margins moderately, and subevenly rounded (pl. 1, fig. 10). Dorsal margin not preserved. Umbone slightly to moderately convex; ventral, ventrolateral, posterior flanks slightly convex medially, becoming flatter toward margin. Dorsoanterior flank abruptly truncated, moderately to narrowly rounded at edge of lunule. Lunule poorly defined, depressed, occupying two-thirds of dorsoanterior margin. Byssal gape unknown, probably long and narrow.

Beaks unknown. Umbo suberect, broad, not well defined. No anterior auricle developed. Posterior auricle, if present, not preserved. Hinge line, internal structures unknown.

Radial ornamentation consisting of 28 to 30 straight simple primary costae extending from early part of umbone to margin. Costae narrow, low, rounded, smooth equally developed, subevenly spaced (more crowded anteriorly), separated by much larger, flat interspaces, a few of which bear very faint, fine, scattered, discontinuous costellae (pl. 1, fig. 8), 1 to 2 per interspace preserved, but probably much more extensive on unworn shells of species. Costellae smooth, straight, very low, rounded. Concentric ornamentation consisting of numerous, crowded, very faint growth lines over entire valve, and a few, scattered, moderately prominent growth lines near margin. Commissure smooth to very broadly undulating.

Remarks: As in *L. (C.) sayrei,* Stephenson did not note the position of the lunule and main byssal gape in this specimen, and considered it a right valve; anterior and posterior are reversed throughout his description.

The holotype is worn, and thus the precise nature of the delicate surface ornamentation cannot be determined. In spite of this, the wide spacing of the costae, lower number of costae, fainter discontinuous costellae, and the smaller, less rounded valve are sufficient to distinguish the species from *L. (C.) sayrei* and *L. (C.) riddlei,* n. sp. The species appears to be most closely related to, and derived from *L. (C.) sayrei.* It is the youngest known member of the lineage. Apparent reduction of the costellae, and retention of well defined costae, may reflect ancestry to the Cenozoic-Recent subgenus *Plicacesta* Vokes.

Stratigraphic and geographic position: The only known specimen is from the upper part of the Peedee Formation, in sediments bearing an Owl Creek-Prairie Bluff fauna (upper part of the zone of *Exogyra costata* Say: Late Maestrichtian). It was found at U. S. Geological Survey locality 13585, in the New Rocky Point quarries, one mile northeast of Rocky Point Station, Pender County, North Carolina.

Type: Holotype, USNM 73431; a nearly complete left valve.

Table 3

MEASUREMENTS: HOLOTYPE OF *LIMA (COSTELLACESTA) INSOLITA* STEPHENSON

Height, including reconstruction of beak (mm)	63
Length (mm)	53.3
Width (mm)	9.8
Distance, anterior margin to beak, along line parallel to hinge axis (mm)	26.4
Angle of inclination, entire valve	105°
Angle of inclination; beak, umbo	85°
Angle between hinge axis and dorsoposterior slope	42°
Angle between hinge axis and dorsoanterior slope	46°
Number of costae 10 mm below beak	28-30
Number of costae in 20 mm length, 20 mm below beak	17
Total terminal number of costae	28-30

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June 30, 1964

EXPLANATION OF PLATE I

Figures

1, 2, — *Lima (Plicacesta) smithi* Sowerby 98

1, Interior and 2, exterior views (X1) of a left valve from Echigo, Japan; USNM 344887; Hirasé Collection, Division of Mollusks, USNM. Illustrated for comparison with members of *L. (Costellacesta).*

3, 4, 6 — *Lima (Costellacesta) riddlei* Kauffman, n. sp. 95

3, Portion of right valve (fig. 4) showing adult ornamentation (X2).

4, Lateral view (X1), holotype (USNM 132632), a right valve.

6, Anterior view (X1) of holotype showing margin of lunule.

5, 7, 9 — *Lima (Costellacesta) sayrei* Stephenson 97

5, Anterior view (X1) of Stephenson's unfigured paratype (USNM 132636) showing limits of lunule, position of byssal gape (space inside byssal gape retouched to improve contrast), infolded anterior margin of cardinal area.

7, Portion of the same adult shell near margin (X2) showing details of ornamentation; left valve.

9, Lateral view of left valve (paratype, USNM 132636, of figs. 5, 7) with auricle broken off.

8, 10 — *Lima (Costellacesta) insolita* Stephenson 99

8, Portion of left valve shown in fig. 10 (X2), showing costae and faint, discontinuous, intercalated costellae.

10, Lateral view (X1) of left valve, the holotype (USNM 73431) and only known specimen.

PLATE I

THE STATUS OF *DEIROCHELYS FLORIDANA* HAY WITH COMMENTS ON THE FOSSIL HISTORY OF THE GENUS

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CONTENTS

		Page
	ABSTRACT	103
I.	"DEIROCHELYS FLORIDANA Hay"	103
II.	FOSSIL DEIROCHELYS RETICULARIA	104
	LITERATURE CITED	106
	PLATE I	105

ABSTRACT

Hay (1908) described an extinct species of chicken turtle, *Deirochelys floridana,* from Pleistocene beds (formerly considered Pliocene), along Peace Creek, Hillsborough County, Florida. His description is based upon a single, complete nuchal bone. A comparison of the type specimen with modern skeletal material demonstrates conclusively that this fossil is not *Deirochelys,* but should be consigned to the genus *Pseudemys* Gray. On the basis of data presently available the fossil cannot be placed with certainty in the extant species *Pseudemys nelsoni* Carr or *Pseudemys floridana* Le Conte, although it is slightly closer to the mean values of the former in some of its proportions.

With *D. floridana* Hay referred to the genus *Pseudemys, Deirochelys* would lack a fossil history except that a partial nuchal element definitely referable to this genus recently has been found in a Pleistocene deposit in Marion County, Florida.

I. "DEIROCHELYS FLORIDANA Hay"

Comparison of a cast (UF 3556) of the type of *D. floridana* Hay (USNM 16679) to a series of nuchal bones of the extant *D. reticularia* (Latreille), reveals striking dissimilarities in most characters. In *D. reticularia* the nuchal bone is a thin, plate-like element, which lacks the massive antero-lateral thickening found in all species of *Pseudemys* available for study. The relatively greater width of the posterior border (and ratios utilizing that dimension) of the nuchal bone of *D. reticularia* further indicate that the fossil was assigned incorrectly to the genus *Deirochelys.* The sculpturing of fine ridges and grooves which has been considered diagnostic of *Deirochelys* and is certainly common in that genus, is duplicated in series of both *P. nelsoni* and *P. floridana.* The type of *D. floridana* is easily distinguished from *Pseudemys scripta* (=*Trachemys scripta*) on the basis of lacking deeply-impressed scute sulci and an even moderately-developed median dorsal keel. From *Pseudemys concinna* it differs in the shape of the anterior border, which also results in a quite different median length—maximum width ratio. It cannot be distinguished clearly from either *P. nelsoni* or *P. floridana.* However, a comparison of series of nuchal bones of *P. nelsoni* and *P. floridana* indicates that the mean widths of their posterior borders (as well as ratios derived

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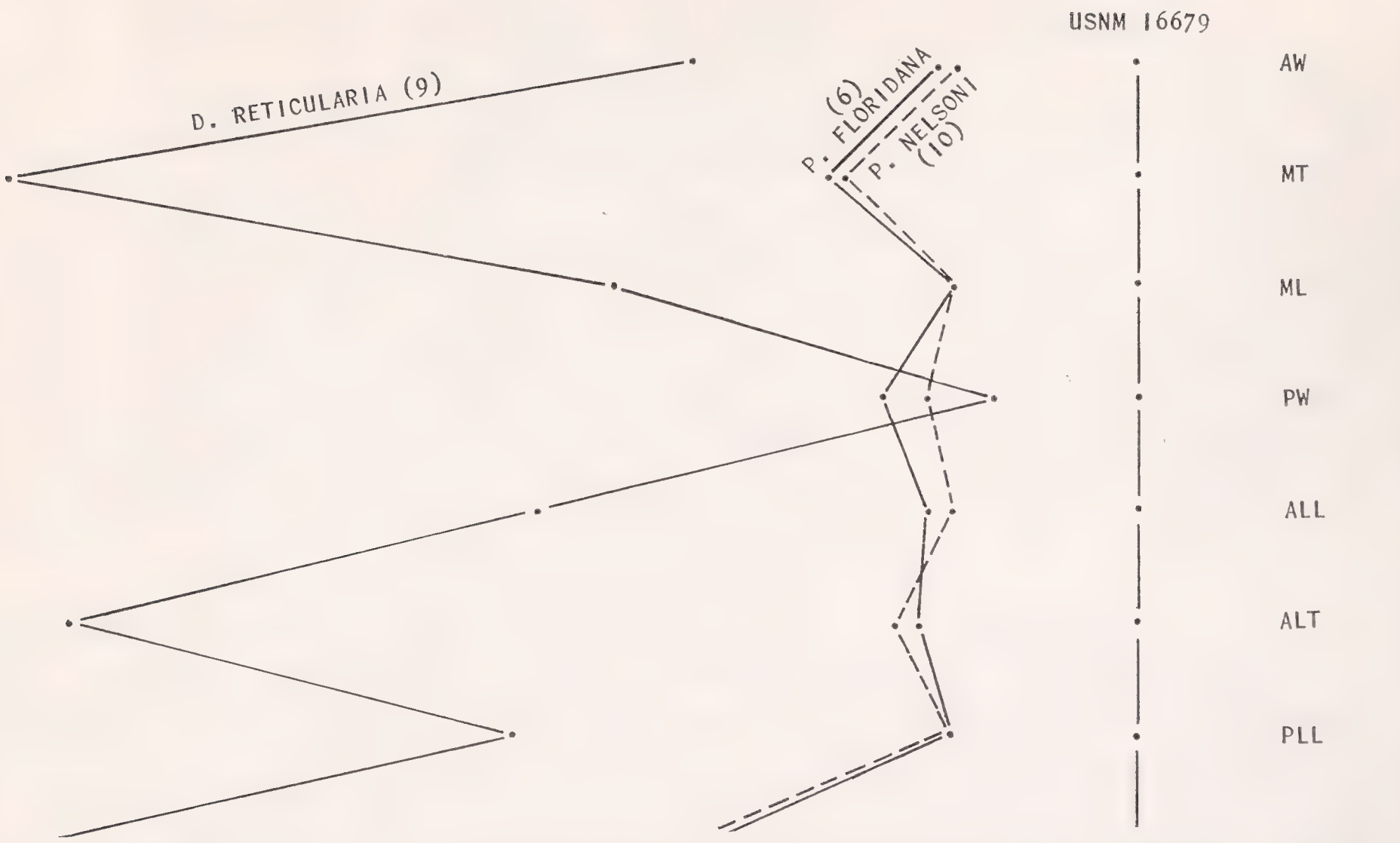

Figure 1. Ratio diagram of dimensions of nuchal bone in several turtles, as labeled. USNM 16679 is the holotype of *D. floridana.* Numbers in parentheses refer to number of specimens. A W = width of anterior border, M T = maximum midline thickness, M L = median length, P W = width of posterior border, A L L = length of anterolateral border, A L T = thickness of anterolateral border, P L L = length of posterolateral border, T P B = thickness of posterior border, M W = maximum width.

therefrom) differ somewhat but the overlap of values makes positive specific identification of single specimens uncertain. This is not surprising as Crenshaw (1955) experienced difficulty in consistently differentiating these forms on the basis of both preserved and living material, and agreed with Carr (1952) that occasional hybridization occurs between the species.

A ratio diagram (Fig. 1) shows the similarity in the proportions of the type of *Deirochelys floridana* and a series of nuchal bones of Recent *P. nelsoni* and *P. floridana.* The marked dissimilarity in proportions between the type specimen and a series of Recent *D. reticularia* is quite evident. The only appreciable deviation of the series of Recent *Pseudemys* from the proportions of the fossil is in the relative thickness of the posterior border. However, due to the large size of the fossil element, this difference may be more apparent than real. In only two of the Recent specimens examined, UF 18128 *(P. floridana)* and UF 5960 *(P. nelsoni),* are any dimensions of the nuchal equal to or greater than those of the fossil. Both were intact shells and the thicknesses of their midlines and posterior borders could not be measured.

II. Fossil Deirochelys reticularia

In 1961, a University of Florida field party under the direction of Clayton E. Ray collected a partial nuchal bone of *Deirochelys* (UF 9292) from a Pleistocene deposit of Illinoian age (Brodkorb, 1959) at the Cummer Lumber Company limestone pit near Kendrick, Marion County, Florida. In most respects the fossil agrees rather well with the nuchal bone of the extant form *D. reticularia.* Its dimensions are as follows: width of anterior border—27 mm; maximum width—approx. 64 mm; *i.e.,* 32 mm x 2; length of anterolateral border—41 mm;

Plate I

Dorsal view of nuchal bones of fossil and Recent *Deirochelys* and *Pseudemys:* A. Recent *D. reticularia* (J-131). B. fossil *D. reticularia* (UF 9292). C. *D. floridana* Hay (cast of type, USNM 16679). D. *P. nelsoni* (UF 17942). E. *P. floridana* (UF 17943).

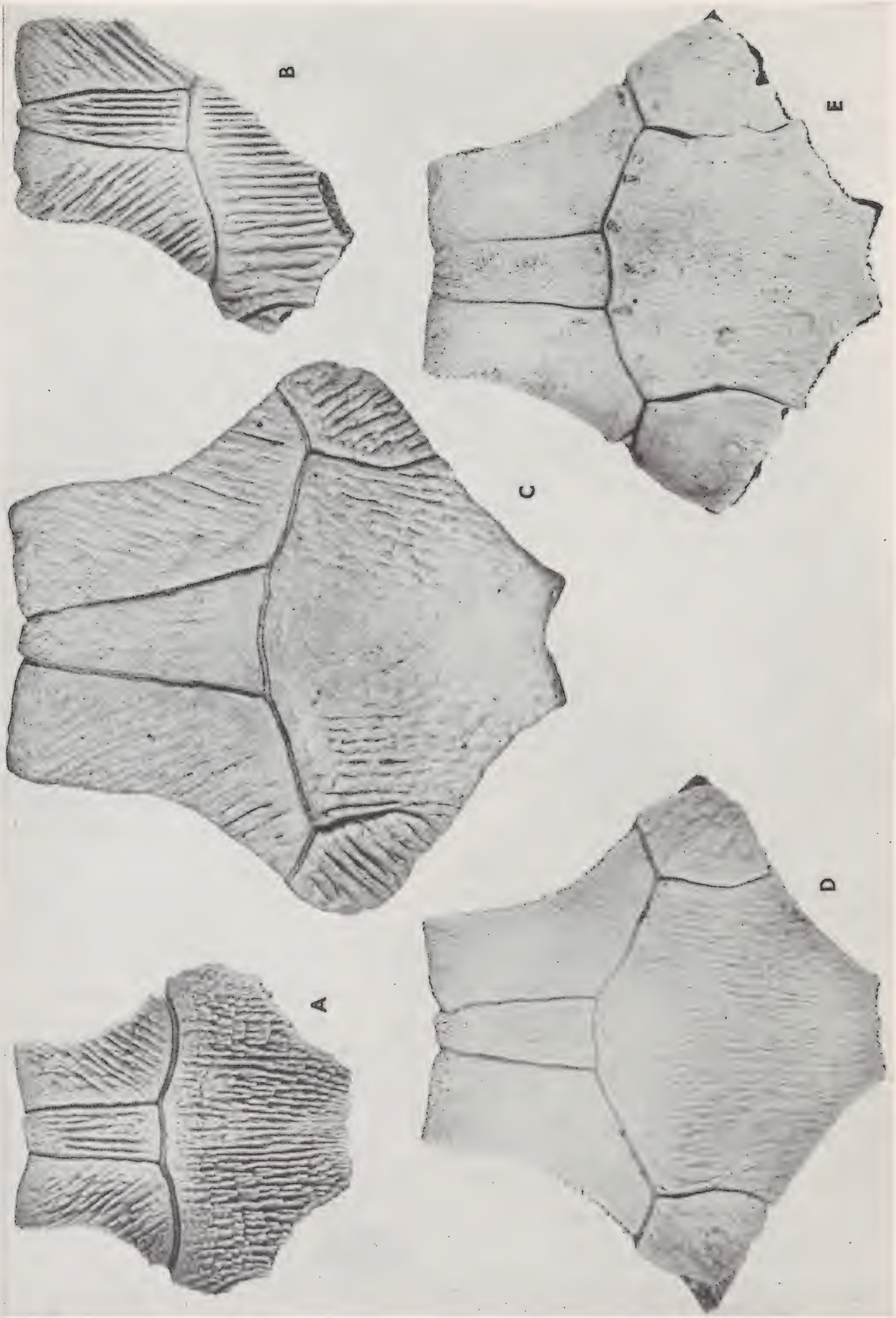

PLATE I

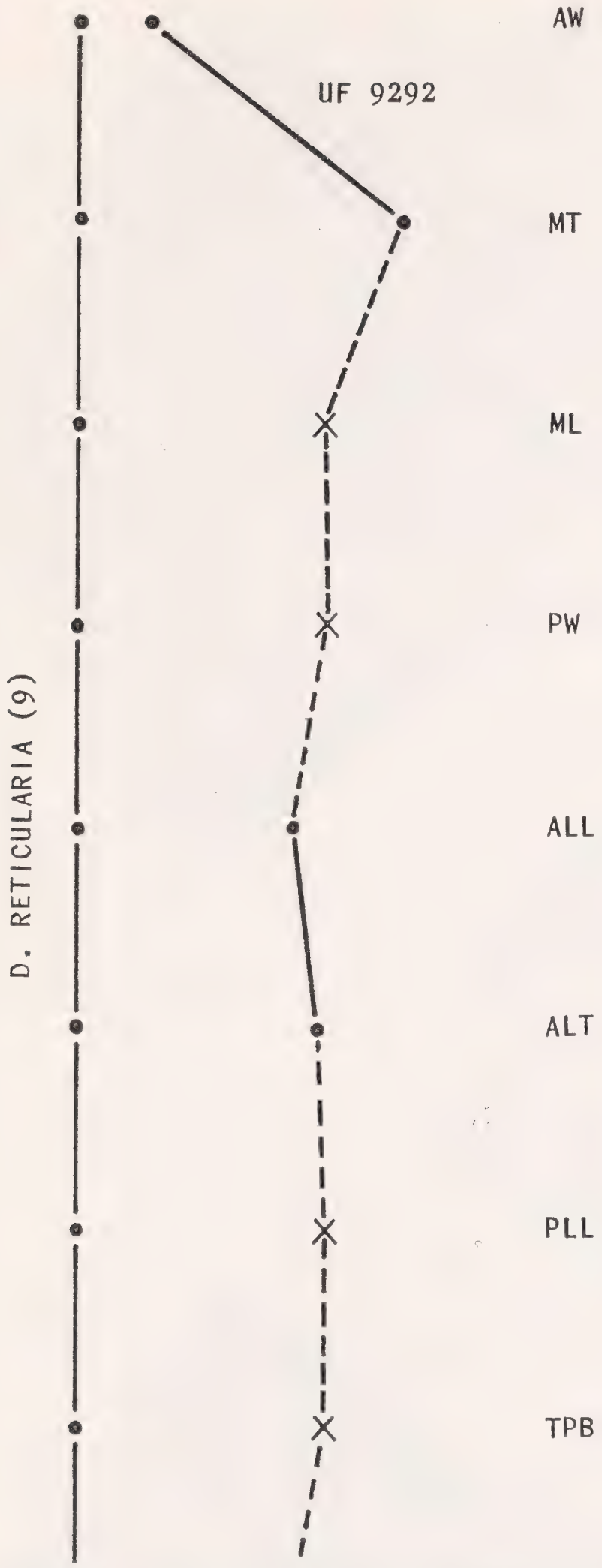

Figure 2. Ratio diagram comparing varicus dimensions of fossil *Deirochelys* (UF 9292) and a series of Recent *D. reticularia.* Abbreviations same as in Fig. 1. X = estimated dimension.

thickness of anterolateral border—10 mm. Dimensions which could not be measured because of the partial nature of the specimen are estimated in the ratio diagram (Fig. 2) which compares the fossil element with a series of Recent *D. reticularia.*

In Plate I the dorsal views of the isolated nuchal bones of the holotype of *D. floridana* and the Marion County fossil fragment (UF 9292) are compared with those of *Deirochelys reticularia, Pseudemys nelsoni,* and *Pseudemys floridana.* Unfortunately, the only large isolated nuchal bones of the latter two species presently available for photographing do not have the ridged-and-grooved sculpture pattern very well developed. The dorsal surface of the fragment is sculptured with fine parallel ridges and grooves of a type commonly observed in very large individuals of *D. reticularia* but which also occurs frequently in species of the genus *Pseudemys.* The size of the fragment indicates a chicken turtle rather large by Recent standards. However, in this instance absolute size is not considered of any taxonomic significance. In only one character is the fossil unique. The proportionate width of the anterior border is conspicuously less than that found in any specimen of the series of *D. reticularia* examined. This may not be particularly significant as Walter Auffenberg (personal communication) informs me that in specimens of land tortoises possessing an extra pair of peripheral bones, the relative dimensions of other elements in the circumcarapacial series are usually greatly altered—particularly the anterior and posterior members.

Thus, with the exception of the relatively narrow anterior border, the fossil appears to represent a large *Deirochelys reticularia* (Latreille). It is considered conspecific with that form until better material is available that might suggest otherwise. Based on this specimen, a fossil history extending to at least the middle Pleistocene of Florida is established for the monotypic genus *Deirochelys.*

Specimens examined in this study are deposited in the collections of the United States National Museum (USNM), The University of Florida (UF), and the author's personal collection (J). Mr. Robert McFarlane kindly made the photographs.

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June 30, 1964

REVIEW

PRINCIPLES OF PALEOECOLOGY: A REVIEW

HUBERT C. SKINNER
TULANE UNIVERSITY

PRINCIPLES OF PALEOECOLOGY: An introduction to the study of how and where animals and plants lived in the past, by Derek V. Ager (Imperial College, London). Published by McGraw-Hill Book Company, New York, 1963, xi + 371 pp., illustrated, $10.75.

Paleoecology is a new, active, and rapidly developing field of geologic research. In the past several decades an imposing body of diversified literature related to fossils and their environments has arisen. The result has been a somewhat incoherent and ill-defined field of investigation for the paleoecologist. Paleoecology has required definition and Dr. Ager provides much to satisfy this demand. This is the first textbook on paleoecology published in English.

The book is divided into three sections. Part One introduces the subject, its scope and limitations, and treats of the nature and classification of environments.

Part Two includes nine chapters, each of which deals with a particular approach or method in the study of paleoautecology (the ecology of individual fossils and fossil groups): comparison with living representatives, deductions from morphology, orientation, organic associates, evidence of activity, associated sediments, lateral variation, geographical distribution of single taxonomic groups, and changes in habitat and habit.

In Part Three, methods of paleosynecology (the ecology of fossil assemblages) are presented in six chapters: comparison with living assemblages, other geological evidence, density and diversity, relationships between species, lateral and vertical changes in assemblages, and geographical distribution of assemblages. A seventh chapter concludes this section with four paleoecological syntheses.

Two appendices follow the text: 1, Glossary of paleoecological terms; and 2, Field questionnaire. These are followed by a lengthy bibliography and a thorough index.

In introducing his subject, the author compares the materials studied by the paleoecologist with a parking lot full of abandoned earlier models of automobiles, stating: "The ecologist's automobile is dynamic in space but static in time; the paleoecologist's automobiles are static in space but dynamic in time." Thus, he aptly describes the greater task confronting the student of fossils and fossil environments.

"Uniformitarianism — the main method and basis of geological reasoning—is equally applicable to paleoecology." With this statement Dr. Ager admits our necessary commitment to this basic principle, though cautioning that change through time is inevitable and must be considered.

The book is well illustrated with specific examples from the rock record. These are widely distributed geographically and through geologic time. It is refreshing that the author—unlike many Europeans—is sufficiently conversant with the literature on North America to include numerous examples from the strata of this continent. Suitable attention is given to experimental and statistical techniques. Field procedures are discussed. It is commendable that the examples of data presentation used to illustrate methods are taken from actual studies.

The language is clear, logical and remarkably uncomplicated by the proliferation of new terminology which mars many similar works. The text is fairly objective with one obvious exception. References to the hypotheses of continental drift and polar wandering are made in several places, but they are dismissed perfunctorily and even humorously. These concepts deserve more thorough treatment, even though the author clearly is not a "drifter."

In summary, this book is well written, comprehensive, and lucid. It will be welcomed by paleontologists and will occupy a convenient niche on their reference shelves.

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MIOCENE PLANKTONIC FORAMINIFERA FROM NEWPORT BAY, CALIFORNIA
JERE H. LIPPS
UNIVERSITY OF CALIFORNIA, LOS ANGELES p. 109

MARGARITARIIDAE, NEW FAMILY (PELECYPODA) AND DESCRIPTION OF TWO NEW SPECIES
HAROLD E. VOKES
PROFESSOR OF GEOLOGY
TULANE UNIVERSITY p. 135

REVIEWS: TIME IN STRATIGRAPHY; NATURAL HISTORY; INTRODUCTION TO GEOLOGICAL MICROBIOLOGY
HUBERT C. SKINNER
TULANE UNIVERSITY p. 143

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CONTENTS

Page

I. Abstract 109
II. Introduction 109
III. Stratigraphy 110
IV. Correlation 112
V. Basis for Classification 114
VI. Systematic Descriptions 115
References Cited 130
Plate I 119
Plate II 123
Plate III 127
Plate IV 131

I. Abstract

Twenty species of planktonic foraminifera are reported from the Miocene Monterey Shale at Newport Bay, California. Rocks of the Luisian Stage contain numerous individuals and species; those of the overlying Mohnian Stage contain fewer species and individuals. Two local zones, recognized in the Luisian, are tentatively correlated with the lower *Globorotalia fohsi* Assemblage Zone in Trinidad (Burdigalian). Higher parts of the Mohnian may correlate with the Helvetian.

The classification adopted in this paper is based on the surface texture of the test. Forms with hispid tests (spinose when living) are separated from smooth and pitted forms (non-spinose when living). This criterion has been utilized for distinguishing taxa at all systematic levels. *Protentella* gen. nov. (type species, *P. prolixa* sp. nov.) is described from the upper Luisian. Six new species are described: *Turborotalia lata, Globigerina tecta, Protentella prolixa,* and *Globorotaloides trema* from the Luisian; and *Globigerina bramlettei* and *Eoglobigerina operta* from the Mohnian.

II. Introduction

Planktonic foraminifera have proved useful in age determination and correlation of Miocene rocks in many parts of the world. Although a sequence of planktonic foraminiferal zones has been recognized throughout

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the world, recognition of these zones or the establishment of new ones has not been attempted seriously in California. To date, California micropaleontologists have utilized the stages and zones of Kleinpell (1938) established on the basis of benthonic foraminifera. Because the distribution of benthonic foraminifera is subject to control by sea bottom conditions which vary sharply from place to place, some discrepancies in correlation of these stages and zones have arisen. As planktonic foraminifera are apparently independent of bottom conditions, their distribution may allow more accurate correlation.

Study of the Miocene planktonic foraminifera from various parts of California (now in progress) has revealed the presence of many species, of value in correlation and age dating. A particularly rich planktonic biota is contained in rocks exposed along the east shore of Newport Bay, California (Figure 1). The foraminifera recorded from this biota (Table 1), provide a basis for further investigations of the California Miocene planktonic species and their use in stratigraphic and ecologic interpretations.

This study was undertaken during 1963 while the writer was a summer student employee at California Research Corporation, La Habra. The Corporation financed much of the field and laboratory work, as well as illustrations and drafting. Alfred R. Loeblich and Helen Tappan Loeblich assisted in the field and in critical review of the manuscript. Frances L. Parker permitted access to the collections of planktonic foraminifera at Scripps Institution of Oceanography, and type specimens also were loaned for study by the U. S. National Museum.

III. Stratigraphy

The rocks in the area of Newport Bay have been arched into an anticline along whose limbs Miocene to Pleistocene sediments crop out (Vedder, Yerkes, and Schoellhamer, 1957). These rocks, best exposed on the northern limb of the anticline, include the Miocene Monterey Shale, Mio-Pliocene Capistrano Formation, and unnamed Plio-Pleistocene sediments. Samples for this study were taken in the Monterey Shale, beginning with the oldest rocks exposed in

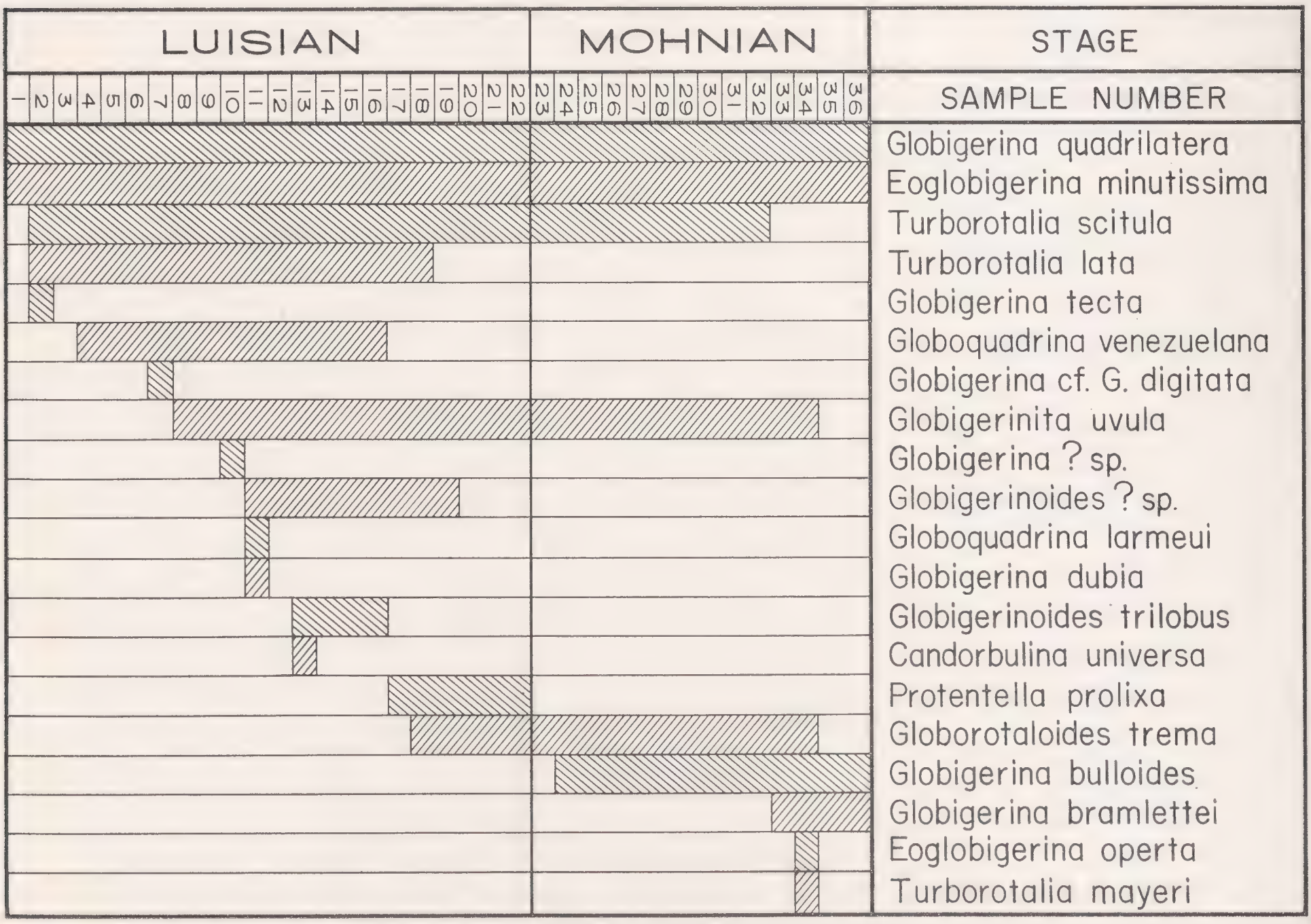

Table 1—Stratigraphic distribution of planktonic foraminifera in part of the Miocene Luisian and Mohnian stages exposed at Newport Bay, California.

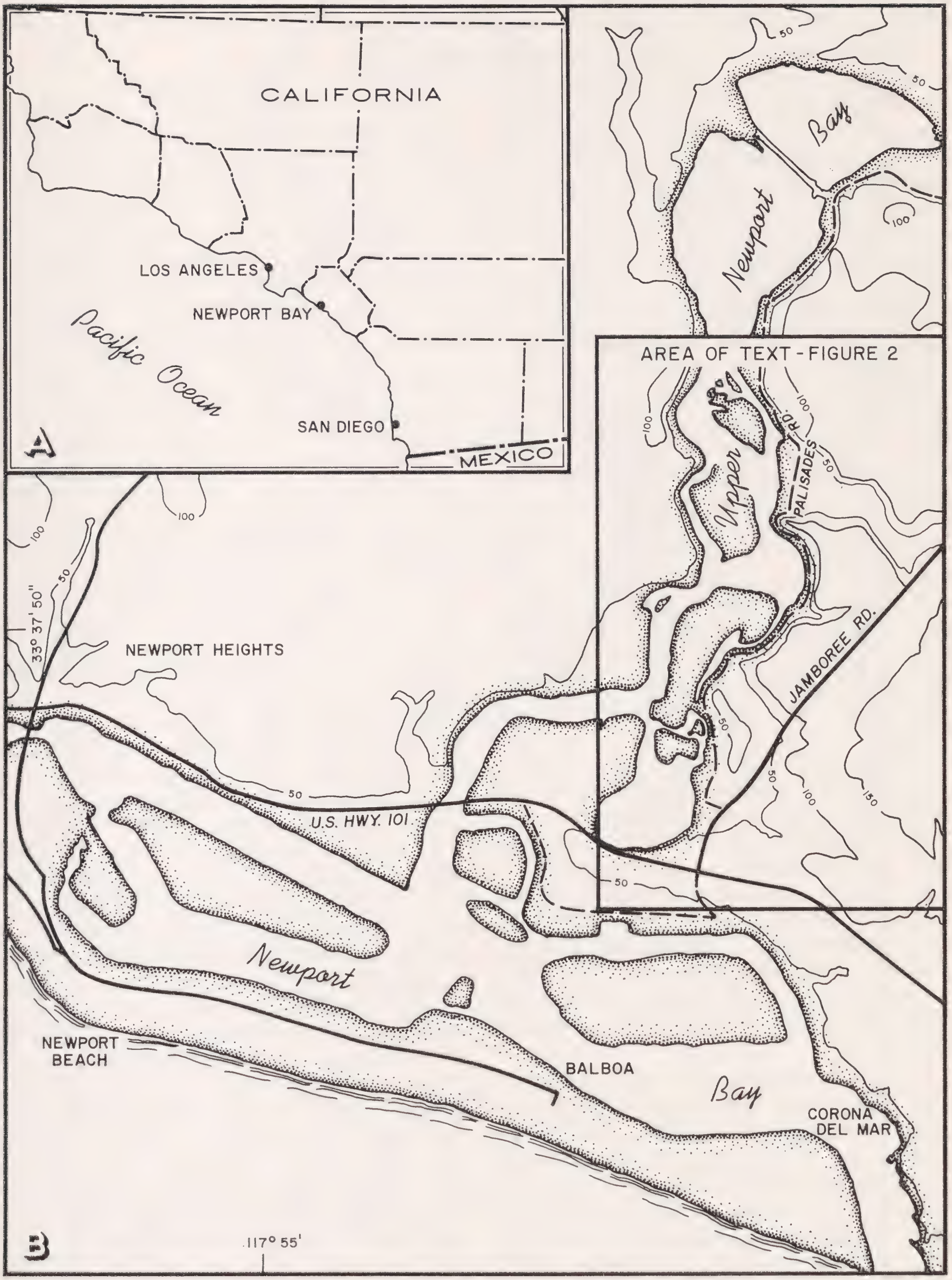

FIGURE 1

A. Map of Southern California showing the location of Newport Bay.
B. Newport Bay region showing the area of Figure 2.

the crest of the anticline and progressing northward up the section (Figure 2).

The strata consist of a continuous sequence of diatomaceous mudstones, with a few chert and sandy interbeds. The beds have slumped several feet along the shore of the bay where the samples were collected, but observed displacements in the sequence were compensated, and it is believed that even undetected displacements will not alter the results of this study. The benthonic foraminifera are indicative of the upper part of Kleinpell's (1938) Luisian (samples 1 to 22) and the lower part of his Mohnian (samples 22 to 36) Stages.

The Luisian rocks at Newport Bay are characterized by a large and diverse planktonic foraminiferal fauna. *Globigerina quadrilatera* and *Eoglobigerina minutissima* are present in great abundance. These species persist into the Mohnian but occur much less commonly. Fifteen other species also are present in the Luisian, and although generally rare they locally may be quite abundant. *Turborotalia scitula* and *Globorotaloides trema* also persist into the Mohnian; the former in about the same relative abundance, the latter becoming somewhat less common.

No distinctive zones can be recognized in the lowest ten samples. *Globigerina tecta* is abundant in sample 2, but this species may prove to have a much greater vertical range elsewhere. Samples 11 to 16 constitute a local zone containing abundant specimens of *Globoquadrina venezuelana, Globigerinoides trilobus,* and *Candorbulina universa.* The uppermost Luisian samples (17 to 22) are characterized by *Protentella prolixa* and moderate numbers of typical *Globorotaloides trema.*

In the Mohnian, the quantity of individuals and number of species of planktonic foraminifera greatly decreased. The vertical distribution is patchy with certain species appearing and disappearing at various levels. The Mohnian is characterized by an assemblage of *Globigerina bulloides* and *Eoglobigerina minutissima. Eoglobigerina operta,* which may prove useful in correlation, and *Turborotalia mayeri* first appear in the uppermost part of the section examined. Ingle (1963) reported *Globigerina pachyderma* from the Mohnian in the area of Newport Bay. This species was not found in the lower Mohnian during this study, however higher parts of the Mohnian section were not studied.

IV. Correlation

Correlation by means of planktonic foraminifera commonly has been assumed to be precise and world-wide. This assumption does not consider the ecologic requirements of these foraminifera. Planktonic foraminifera are not distributed homogeneously throughout the world simply because they float. Bradshaw (1959) observed that living planktonic foraminifera in the Pacific Ocean were distributed latitudinally in a pattern generally correlated with sea surface temperatures, but also affected by other factors. Belyaeva (1963) found a similar pattern of distribution in the bottom sediments of the Indian Ocean. These and other studies show that tropical regions are characterized by a diverse fauna, that temperate and cooler regions have different and less diverse faunas, and that after death the foraminifera are largely deposited in the areas where they lived. This latitudinal distribution is commonly altered, especially near the edges of these temperature belts, by other oceanographic phenomena. In the geologic past the distribution was probably controlled by similar factors. Since mid-Oligocene a latitudinal temperature gradient has existed along the Pacific Coast (Durham, 1950) as well as elsewhere in the world, and correlation of the warmer-water, low-latitude faunas with those of the cooler, higher latitudes is less certain in the fossil record than is correlation within a single temperature belt.

Planktonic species may differ in morphology, depending on where they live. Some existing species show morphologic variation with latitude (Parker, 1962) which would require splitting into distinct taxa if the criteria utilized by many stratigraphic paleontologists were applied. Much emphasis has been placed on "datums," or the first appearance, of certain species. Such appearances, particularly in the higher latitudes, may only correspond to a change in some oceanographic condition and not to the phylogenetic first appearance. For these reasons, correlation of the Newport Bay planktonic faunas with those of the standard reference sections in tropical America is only *tentative.* Further studies, now in progress on the fossil planktonic faunas of California

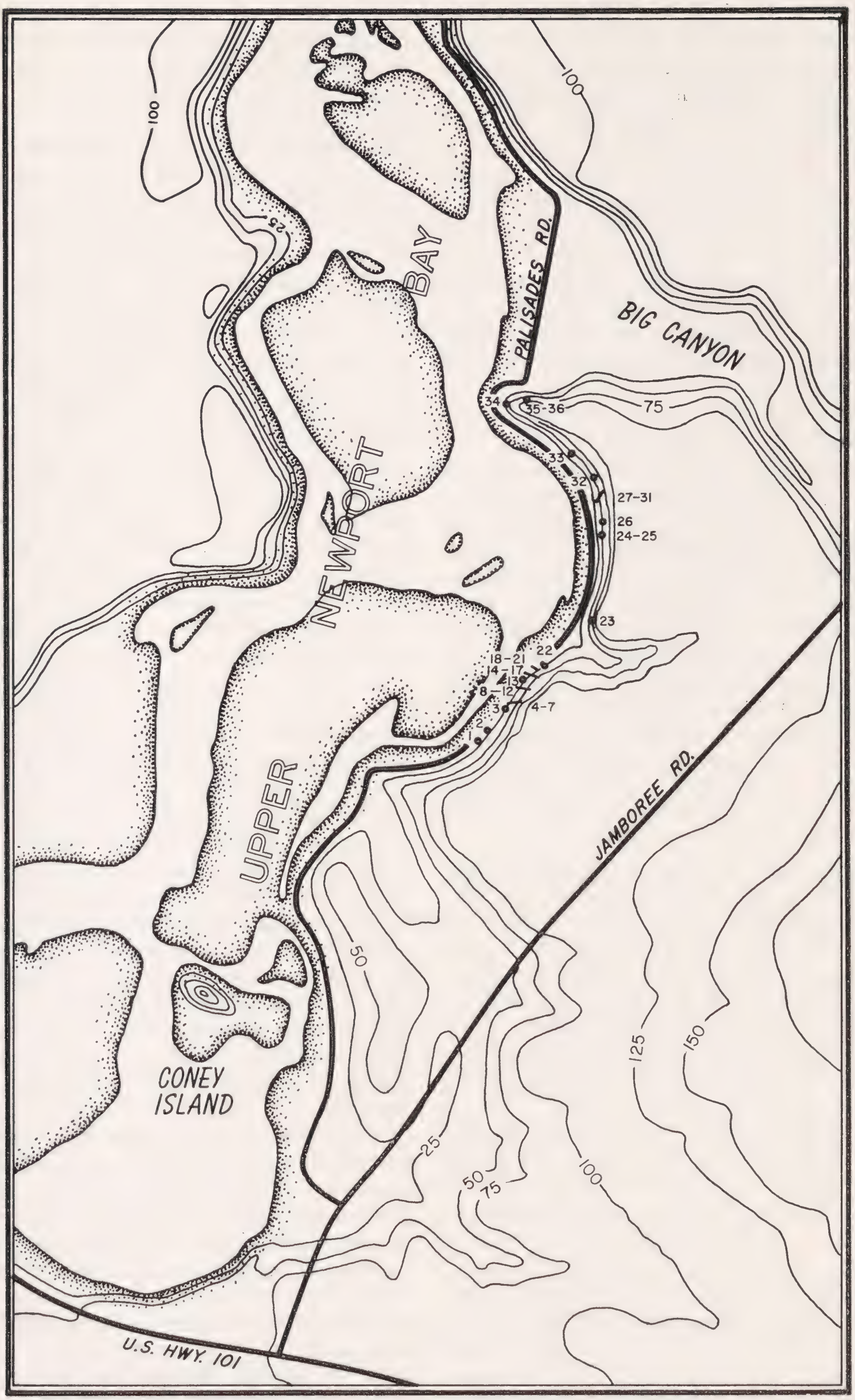

Figure 2—Map of a portion of upper Newport Bay showing the sample localities along the east shore of the Bay.

and other higher latitude areas, must be completed before reliable correlations are possible. Furthermore, as the Miocene sequence of rocks in California is very thick, zones established in other areas may be spread through much more thickness here than in areas of their typical development, and before these zones can be discriminated in California, longer sections of rocks must be examined.

Correlations with the European stages made herein are based on their recognition in the tropical American sequence although the exact correlations of the latter also may be questioned.

Critical studies of Miocene planktonic foraminifera from California have not been published. As a result, correlations within California are not feasible as yet on the basis of these foraminifera. Most of the species occurring at Newport Bay will be found elsewhere in California, and the vertical ranges of some also may be extended.

Correlation of zones based on benthonic foraminifera is questionable because of ecologic factors controlling their distribution even in local areas. Ingle (1963) has stated that stages based on benthonic foraminifera transgress stratigraphic surfaces based on planktonic organisms within the sedimentary basin of which the Newport Bay area was a part.

Most of the previously described planktonic species occurring at Newport Bay have long stratigraphic ranges, hence cannot be utilized for detailed correlations. Some species first appear near the base of the Aquitanian and continue into the upper Miocene or higher (see Bolli, 1957; Blow, 1959). Other species suggest tentative correlations with the standard sections but these are not conclusive.

The assemblage of *Candorbulina universa* at Newport Bay is most similar to assemblages of this species in the lower part of the *Globorotalia fohsi* Assemblage Zone in Trinidad (see Brönnimann, 1951). *Protentella prolixa* closely resembles *Hastigerinella bermudezi* Bolli and these species first appear soon after *C. universa* at Newport Bay and in Trinidad, respectively. This suggests correlation with the lower *G. fohsi* Assemblage Zone of Trinidad, and this zone has been considered Burdigalian in age (Bandy, 1964b).

In a synthesis of planktonic occurrences, Bandy (1964b) recognized an *Orbulina* "datum" (first phylogenetic appearance) at the base of the Burdigalian. There are two published records of pre-Luisian *Orbulina* in California. Bagg (1905) reported *Orbulina* from sediments later determined to be upper Relizian (Kleinpell, 1938, p. 22). Kleinpell examined Bagg's original sample and did not find *Orbulina.* Kleinpell (in Packard and Kellogg, 1934) reported this genus from the upper Saucesian Astoria Formation in Oregon (not from California, as erroneously stated by Bandy and Kolpack, 1963, p. 152). Later study of the Astoria Formation has not revealed the presence of *Orbulina* (Cushman, Stewart and Stewart, 1948). Furthermore, the Astoria Formation is now considered to be at least late Relizian in age (Weaver, *et al.,* 1944). Nevertheless, Bandy and Kolpack (1963, text-fig. 32) placed the lower Burdigalian boundary in the Saucesian based on Kleinpell's statement (1938, p. 346) of its occurrence in Oregon. Loeblich and Tappan (1961) have shown that pre-Miocene records of *Orbulina* in California were based on misidentifications, and the two pre-Luisian records of *Orbulina* mentioned above are doubtful and probably incorrect. The first well documented appearance of orbulinids thus is in the Luisian (Kleinpell, 1938, p. 346). On this basis the Luisian would be of Burdigalian age.

On a world-wide basis, Bandy (1964b, p. 9, 10) reported the appearance of *Globigerina pachyderma* in the lower Helvetian. If Bandy's observation and the occurrence in Mohnian rocks near Newport Bay (Ingle, 1963) represent initial appearances of this species, then part of the Mohnian would be lower Helvetian. This would further indicate Burdigalian age for the Luisian at Newport Bay.

In summary, at Newport Bay the upper part of the Luisian is considered Burdigalian in age and part of the Mohnian is considered Helvetian. The Burdigalian-Helvetian boundary could not be determined within the section studied. Thus, the entire California Miocene may be older than has been suggested by most previous stratigraphers.

V. Basis for Classification

The classification of planktonic foraminifera has recently undergone numerous changes. Various classifications have been proposed based on different criteria. New

information on the biology, history, and morphology of these foraminifera is fast accumulating and as with any subject, this results in rapid change. The classification adopted in this paper has resulted from current studies of the systematics of planktonic foraminifera.

The planktonic environment is ecologically specialized and the same convergent, adaptive morphology can be observed in most planktonic organisms (Hesse, Allee, and Schmidt, 1937, p. 223; Bolli, Loeblich and Tappan, 1957, p. 9). As test form, apertural position and certain apertural modifications are believed to be highly adaptive features which have reappeared several times throughout the geologic record, they are not considered here to be of major taxonomic importance. The structure of the test wall reflects basic physiological and biochemical processes of test formation and thus probably indicates close relationships. The test structure is considered of primary importance in the determination of natural groups of foraminifera (Loeblich and Tappan, 1964, p. C153).

Parker (1962) recognized the importance of this criterion and found that grouping planktonic foraminifera on the basis of the presence or absence on the test wall of long, thin spines resulted in a more meaningful, natural classification. These spines, each a single crystal of calcite (Wood, 1949, p. 240), probably also reflect basic physiologic differences between the foraminifera which have them and those which do not. Planktonic foraminifera are seldom preserved with their spines intact, but the presence or absence of spines in the living organism can be inferred from the texture of the test wall. Those Recent forms with long, thin spines when living have truly hispid tests (Parker, 1962, p. 221). Ujiie (1963) stated that the roughness of the surface was due to the increase in the diameter of the "hollows" on the test. This is true to some degree but the spacing of the hollows and their diameter is dependent on the presence or absence of spines. In this respect, this spacing is a partial measure of spinosity. The character of these hollows may be significant at the specific level, but does not seem to be so at the generic or suprageneric level. Morozova (1958, p. 36) recognized the importance of details of the test wall in taxonomy but did not distinguish taxa based on it. The texture of the test wall is herein utilized as an important criterion for distinguishing taxa at all levels.

Identifications of planktonic species based on a few or single specimens are generally unreliable, due to the great variation within a single species. Previous determinations made on a limited number of specimens may prove to be incorrect when large suites of specimens are examined. Obviously such misindentifications will affect past correlations. Studies of planktonic foraminifera should be made, when possible, on the basis of large assemblages of specimens, a more reliable indication of the variation in the once living populations. Identifications and descriptions in this paper are based on several hundred specimens, except where noted. Complete synonymies are not attempted; generally only the original reference is given, because of the unreliability of identifications based solely on published records or a type specimen unless large suites of paratypes or topotypes are also available. Figured type material of the present paper is deposited in the Invertebrate Type Collections, Department of Geology, University of California, Los Angeles (UCLA), and paratypes of new species are deposited in the U. S. National Museum and at Tulane University.

VI. Systematic Descriptions

Superfamily Globigerinacea Carpenter, Parker, and Jones, 1862

Family Globigerinidae Carpenter, Parker, and Jones, 1862

Parker (1962, p. 220) restricted this family to include only those globigerinid-like species with hispid walls (spinose when living) in the adult or ontogeny. Subfamilies are distinguished herein primarily on the basis of the test wall but also on gross morphology. Further study may indicate that certain subfamilies should not be recognized.

Subfamily Globigerininae Carpenter, Parker, and Jones, 1862

Test trochospiral in adult or ontogeny. Primary aperture umbilical to spiroumbilical, secondary sutural apertures may be present. Wall of adult hispid, spinose when living.

Genus Globigerina d'Orbigny, 1826

Many species that have very different types of test walls have been included in this genus. Loeblich and Tappan (1964, p.

C669) include forms whose walls are smooth, pitted, cancellate, hispid, or spinose. As the type species, *G. bulloides* d'Orbigny, is spinose when living and hispid without the spines, this genus has been restricted by Parker (1962, p. 221) to such forms.

GLOBIGERINA BRAMLETTEI Lipps, sp. nov.

Pl. I, figs. 4a-c

Test free, small, trochospiral, globose, of 2½ to 3 whorls, outline quadrate, lobate, periphery broadly rounded, spiral side convex, spire low to high, sharp, in center of test. Chambers inflated, quadrate in spiral view, oval to quadrate in umbilical view, circular to slightly rectangular in edge view, increasing rapidly in size, 4 in last whorl. Sutures radial, depressed. Wall relatively thin, finely hispid. Aperture umbilical, a low oval, about twice as wide as high to nearly circular, bordered by a small raised commonly upturned lip.

Greatest diameter of holotype .204 mm; greatest thickness .153 mm.

Remarks: Globigerina bramlettei is similar to the warm-water variety of *Globigerina pachyderma* of Parker (1962, p. 224). It differs primarily in its more lobate outline, larger size, and thinner test walls. The aperture in *G. bramlettei* is consistently umbilical in position whereas the apertures of typical and warm-water *G. pachyderma* may tend to be extraumbilical. The surface texture of *G. bramlettei* is finely hispid; that of most specimens of *G. pachyderma* is peculiarly pitted and the wall is much thicker.

Globigerina bramlettei occurs only in the Mohnian.

This new species is named in honor of M. N. Bramlette, Scripps Institution of Oceanography, in recognition of his studies of the Miocene stratigraphy and micropaleontology in California.

Types: Holotype UCLA no. 34713; 100 unfigured paratypes UCLA no. 34714; and 10 unfigured paratypes USNM no. 641565. All types from sample 34, Mohnian.

GLOBIGERINA BULLOIDES d'Orbigny

Pl. II, figs. 1a-c

Globigerina bulloides D'ORBIGNY, 1826, Ann. Sci. Nat. Paris, ser. 1, v. 7, p. 277.

Test free, trochospiral, biconvex, outline lobate, apex in center of test. Chambers globular, increasing slowly in size during ontogeny, 4 to 5 in last whorl. Sutures depressed, radial. Wall calcareous, hispid, coarsely perforate. Aperture umbilical, height generally less than half that of last chamber.

Remarks: The specimens from Newport Bay are identical with topotypes from Rimini, Italy. For comparisons, see remarks under *Globigerina quadrilatera* below.

As restricted in this study, *G. bulloides* first appears in the Lower Mohnian. It is not abundant.

Types: Figured hypotype UCLA no. 34700; and 100 unfigured hypotypes UCLA no. 34701, sample 34, Mohnian.

GLOBIGERINA cf. G. DIGITATA Brady

Pl. II, figs. 2a-c

? *Globigerina digitata* BRADY, 1879, Quart. Jour. Micr. Sci., new ser., v. 19, p. 286.

Test free, small, trochospiral, consisting of three whorls, spiral side flattened. Chambers spherical in early stages, elongate in last formed, each increasing about twice the size of the preceding, four in last whorl. Sutures radial, depressed, distinct. Wall finely hispid with small pores. Aperture umbilical, circular, bordered by narrow poreless rim.

Remarks: This identification is based on one specimen and is therefore questionable. Although much additional sample was examined, more specimens could not be found. The specimen could be an aberrant *Globigerina quadrilatera,* which occurs abundantly but intermediate specimens are absent. The present specimen is identical to small specimens of *G. digitata* from the central Pacific Ocean. It differs from typical examples of the species only in its smaller size and fewer elongate chambers.

Globigerina digitata is the type species for the genus *Beella* Banner and Blow, but is here retained in *Globigerina* following Parker (1962, p. 222).

Type: Figured hypotype UCLA no. 34704, sample 6, Luisian.

GLOBIGERINA DUBIA Egger, 1857

Pl. I, figs. 5a-c

Globigerina dubia EGGER, 1857, Neues Jahr. Mineral. Geogn., Petrefak.-Kunde, 1857, p. 281, taf. 9, figs. 7-9.

Test free, small to medium in size, trochospiral, spiral side flattened or slightly convex, outline lobate, circular, periphery rounded. Chambers spherical, increasing evenly and slightly in size with growth, commonly five but may be four in last whorl. Sutures radial, distinct, depressed, sharp to "U"-shaped. Wall hispid, perforate, pores randomly spaced, small. Aperture umbilical, a low arch, bordered by a smooth to ragged lip which may be a tooth-like projection.

Remarks: The specimens from Newport Bay are identical with topotypes of this species from the Maierhof Meersand, Bavaria. For comparison see remarks under *Globigerina quadrilatera* below.

This species occurs in its typical form only in sample 11 (Luisian) where it is the dominant *Globigerina* present. A few specimens of *Globigerina quadrilatera* also occur there, but the two species do not intergrade.

Types: Figured hypotype UCLA no. 34702, sample 11, Luisian; 200 unfigured hypotypes UCLA no. 34703, sample 11, Luisian.

GLOBIGERINA QUADRILATERA Galloway and Wissler

Pl. I, figs. 1a-3c

Globigerina quadrilatera GALLOWAY and WISSLER, 1927, Jour. Paleontology, v. 1, no. 1, p. 44, pl. 7, fig. 11a-c.

Test free, a low to high trochospire of 2½ whorls, biconvex, outline lobate, periphery rounded, apex of spire in center of test. Chambers globular, rapidly enlarging as added, all visible on spiral side, smaller terminal chamber present on some specimens. Sutures radial, deeply depressed, incised or U-shaped. Wall calcareous, perforate, hispid, perforations of varying size randomly distributed on surface. Aperture large, open, umbilical to spiroumbilical, bordered by narrow non-spinose rim.

Remarks: Ths species shows much variation in size and morphology, from large specimens with big spiroumbilical apertures (Plate I, figures 2a-c) to smaller forms with small, restricted apertures (Plate I, figures 1a-c). Further study of these variations elsewhere may reveal that more than one species has been included herein, although all of these variations intergrade in single samples and between samples. The assemblage as a whole is unlike assemblages of other species of *Globigerina,* hence all variations are considered to belong to single populations of *G. quadrilatera.* The species also closely resembles *G. dubia* and *G. bulloides,* both of which may occur with it. However, comparison of large series of topotypes of the three species shows that *G. quadrilatera* differs from *G. bulloides* by its much more rapidly increasing chamber size with growth and, in general by its larger and higher aperture. *Globigerina dubia* is commonly lower-spired and smaller with the chambers increasing more regularly in size. Its aperture is smaller, nearly always umbilical in position but tending in some specimens to be umbilical-extraumbilical, and bordered by a narrow rim which is commonly jagged.

These three species were found to vary in proportional abundance. In samples where *Globigerina dubia* or *G. bulloides* occurred, the abundance of *G. quadrilatera* was greatly decreased. Possibly the three forms are phenotypic variants of a single species, their morphology differing, perhaps, because of varying environmental factors. In the Luisian, *G. quadrilatera* is extremely abundant, commonly comprising 60-90 per cent of the foraminifera in a sample. This species varies greatly in Luisian samples that contain planktonic species indicating tropical or near tropical conditions.

Apparently with the influx of cooler water in the Mohnian, the previously abundant *G. quadrilatera* almost disappeared and *Globigerina bulloides* became the common planktonic species. In certain Mohnian samples, *G. quadrilatera* is quite abundant. Further study of these and other closely related species must be undertaken before definite conclusions about their relationships can be reached.

Globigerina quadrilatera occurs in all Luisian and most Mohnian samples at Newport Bay. It has also been observed in younger deposits in California.

Types: Figured hypotypes UCLA no. 34705 from sample 16; no. 34706, from sample 13, no. 34707, from sample 9; all are Luisian. Two hundred unfigured hypotypes UCLA no. 34708, sample 1, Luisian; 200 unfigured hypotypes UCLA no. 34709, sample 13, Luisian; 50 unfigured hypotypes UCLA no. 34710, sample 34, Mohnian.

GLOBIGERINA TECTA Lipps, sp. nov.

Pl. I, figs. 6a-c

Test free, small, trochospiral, 2½ to 3 whorls, flattened to slightly convex on both sides, umbilicus small, deep when uncovered, outline lobate, periphery rounded. Chambers inflated, increasing slightly in size with growth, circular to slightly rectangular in side view, ovate in umbilical and edge views, final chamber with elongation covering umbilicus in most specimens. Sutures distinct, radial, in narrow depression. Wall coarsely hispid. Aperture an umbilical arch of differing height, at end of extension of terminal chamber.

Greatest diameter of holotype .208 mm; greatest thickness .102 mm.

Remarks: This new species is similar to *Globigerina quinqueloba* described from Recent sediments off Southern California (Nat-

land, 1938). In the spiral view, the chambers of *G. tecta* are generally ovate, whereas those of *G. quinqueloba* are rectangular. In general, *G. tecta* has more chambers (5 to 7) than *G. quinqueloba* (4 to 5), and the final chamber does not cover the umbilical area as completely. The spire of *G. tecta* is most commonly flat whereas that of *G. quinqueloba* varies from flat to mainly convex. These two species appear to be very closely related. Forms intermediate in age have not been described nor figured, hence inferences as to the relationship of the Miocene species to the Recent one as yet cannot be made.

Although the final chamber and apertural characters are similar to typical *Globigerinita,* this new species is placed in *Globigerina* because of the distinctly hispid test. It is closely similar to *Globigerina quinqueloba,* which Parker (1962, p. 225) also considered to be a true *Globigerina,* on the basis of surface wall character.

Globigerina tecta is common in sample 2 (Luisian).

The specific name is from the Latin *tectus* meaning "cover," in reference to the modified last chamber which covers the umbilical area.

Types: Holotype (Plate I, figures 6a-c) UCLA no. 34711; 100 unfigured paratypes UCLA no. 34712. All types from sample 2 (Luisian).

Globigerina? sp.

Pl. I, figs. 7a-c

Test free, highly trochospiral, of 3½ whorls, highly convex on spiral side, outline lobate, periphery broadly rounded. Chambers globular, inflated, increasing rapidly with growth, 4 in last whorl. Sutures radial, deeply depressed in later whorls, slightly so in early whorls. Wall calcareous, thin, finely hispid. Aperture umbilical, a small oval slit at base of final chamber, with small lip on upper edge.

Remarks: This species appears to be distinct from all other species at Newport Bay, but its rarity prevents specific identification. The high spire and low umbilical aperture are similar to those of *Globigerinita uvula* (Ehrenberg), but the present form differs in its larger size and more hispid test. The degree of hispidity suggests that this species is a *Globigerina* although *Globigerinita* may also be finely hispid (Parker, 1962, p. 253).

Types: Figured specimen UCLA no. 34715, 5 additional specimens UCLA no. 34716, sample no. 18, Luisian.

Plate I

(All figures: a. spiral view, b. umbilical view, c. edge view, unless otherwise noted)

Figures — Page

1. *Globigerina quadrilatera* Galloway and Wissler 117
Small individual (UCLA 34705) with restricted aperture. x 135. Luisian

2. *Globigerina quadrilatera* Galloway and Wissler 117
Large individual (UCLA 34706) with a big spiroumbilical aperture. x 65. Luisian

3. *Globigerina quadrilatera* Galloway and Wissler 117
Typical individual (UCLA 34707). x 35. Luisian

4. *Globigerina bramlettei* Lipps sp. nov. 116
Holotype (UCLA 34713). x 190. Mohnian

5. *Globigerina dubia* Egger 116
Hypotype (UCLA 34702). x 85. Luisian

6. *Globigerina tecta* Lipps sp. nov. 117
Holotype (UCLA 34711). x 190. Luisian

7. *Globigerina?* sp. 118
Figured specimen (UCLA 34715). x 95. Luisian

All illustrations by Margaret Rogers.

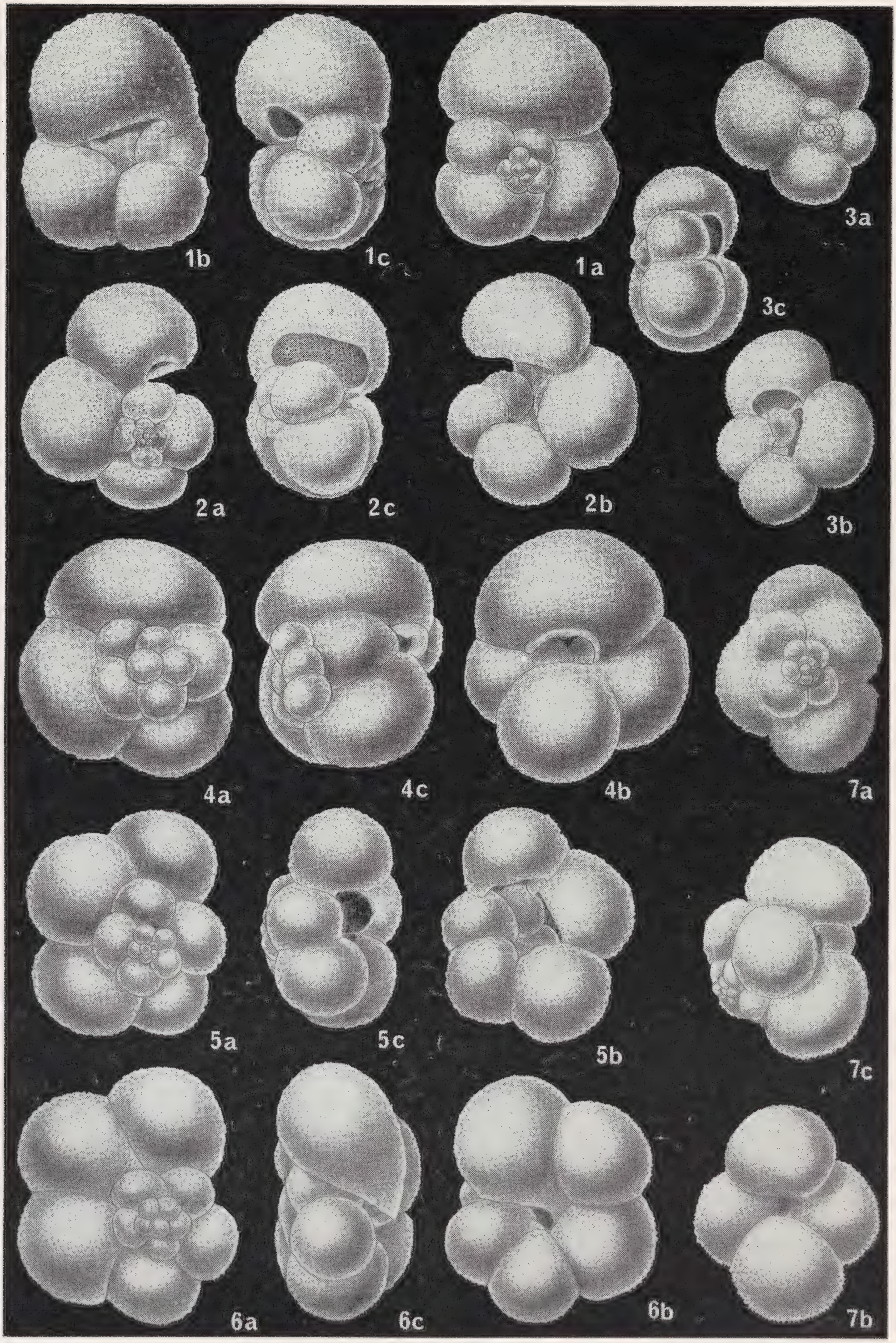

PLATE I

Genus GLOBIGERINOIDES Cushman, 1927

GLOBIGERINOIDES TRILOBUS (Reuss)

Pl. II, figs. 3a-c

Globigerina triloba REUSS, 1850, Denkschr. Akad. Wiss. Wien. Math.-Nat. Classe, v. 1, p. 374.

Test free, large, trochospiral, of about 2½ whorls, outline trilobate to quadrilobate, periphery broadly rounded. Chambers spherical, increasing rapidly in size, generally 4 in last whorl. Sutures radial, deeply depressed in later stages. Wall coarsely perforate, forming pits on exterior surface, spines of earlier chambers commonly preserved in the interior, when enveloped by later chambers. Primary aperture umbilical, a low flattened arch extending over the umbilical margins of the previous three chambers, supplementary apertures semicircular to slit-like arches at intersection of radial and spiral sutures on spiral side.

Remarks: Typical specimens occur in samples 13 to 16 (Luisian) and are most numerous in 14 and 15.

Banner and Blow (1960) designated a specimen of *Globigerinoides trilobus* as the lectotype of *Globigerina quadrilobata,* but Bandy (1964a) noted the invalidity of this selection. Bandy's opinion is followed here.

Types: Figured hypotype UCLA no. 34717, sample 16; 50 unfigured hypotypes UCLA no. 34718, sample 16; 50 unfigured hypotypes UCLA no. 34719, sample 13. All Luisian.

GLOBIGERINOIDES? sp.

Pl. II, figs. 4a, b

Test free, of small to medium size, trochospiral, outline lobate, periphery rounded, spiral side convex, umbilical side flattened. Chambers spherical, increasing slightly in size with growth, four in last whorl. Sutures radial, depressed, distinct. Wall hispid, finely perforate. Primary aperture umbilical, ovate to a low arch; small, oval to triangular, secondary aperture on spiral side at junction of spiral and radial suture of last-formed chamber.

Remarks: Only a few specimens of this form were found in the Luisian strata. The general proportions of the test and chambers are similar to those of *Globigerina quadrilatera* and they may be aberrant specimens of this *Globigerina.*

Types: Figured specimen UCLA no. 34720; 5 unfigured specimens UCLA no. 34721; sample 18, Luisian.

Subfamily ORBULININAE Schultze, 1854

Test trochospiral, later stage enveloping previous chambers. Wall hispid, spinose when living, perforate. Primary aperture not visible in adult, secondary apertures multiple, sutural or areal in position.

This subfamily cannot be differentiated on the basis of spinosity, but is recognized by the distinctive enveloping final stage. Genera here included are very closely related to the Globigerininae and possibly should be included therein.

Genus CANDORBULINA Jedlitschka, 1934

Candorbulina JEDLITSCHKA, 1934, Naturf. Ver. Brünn, Verh., Brünn, Tschechoslowakei, Bd. 65(1933), p. 20.

Praeorbulina OLSSON, 1964, Jour. Paleontology, v. 38, no. 4, p. 770.

Type species: Candorbulina universa Jedlitschka, 1934, fixed by monotypy.

Test free, trochospiral in early part, circular or lobate in outline. Chambers globular, last chamber partially enveloping previous chambers, final two or three chambers enlarged in some specimens. Sutures radial, distinct. Wall of calcite, radial, bilamellid, perforate, perforations of differing sizes, hispid. Apertures multiple, umbilical in early trochospiral stages, sutural in adult, some areal near sutures.

Remarks: Candorbulina is here considered to be a distinct genus, including those orbulinids with multiple apertures along the sutures between the last spherical chamber and the earlier trochospiral whorls. It is distinguished from *Orbulina* d'Orbigny by the multiple sutural apertures which are lacking in true *Orbulina.* Confusion exists as to the generic status of *Candorbulina,* because the generic name has been frequently used for true *Orbulina* in which the trochospiral stages protrude through the last chamber but which do not possess sutural apertures (Figure 3). The forms without sutural apertures can be found in any normal Miocene to Recent population of *Orbulina* but should not be confused with *Candorbulina. Candorbulina* is differentiated by the possession of sutural apertures and not by the protruding early trochospire. *Praeorbulina* is here regarded as a synonym of *Candorbulina* and their type species are regarded as synonymous.

The present genus is apparently restricted to the middle Miocene, whereas true *Orbulina* ranges from Miocene to Recent.

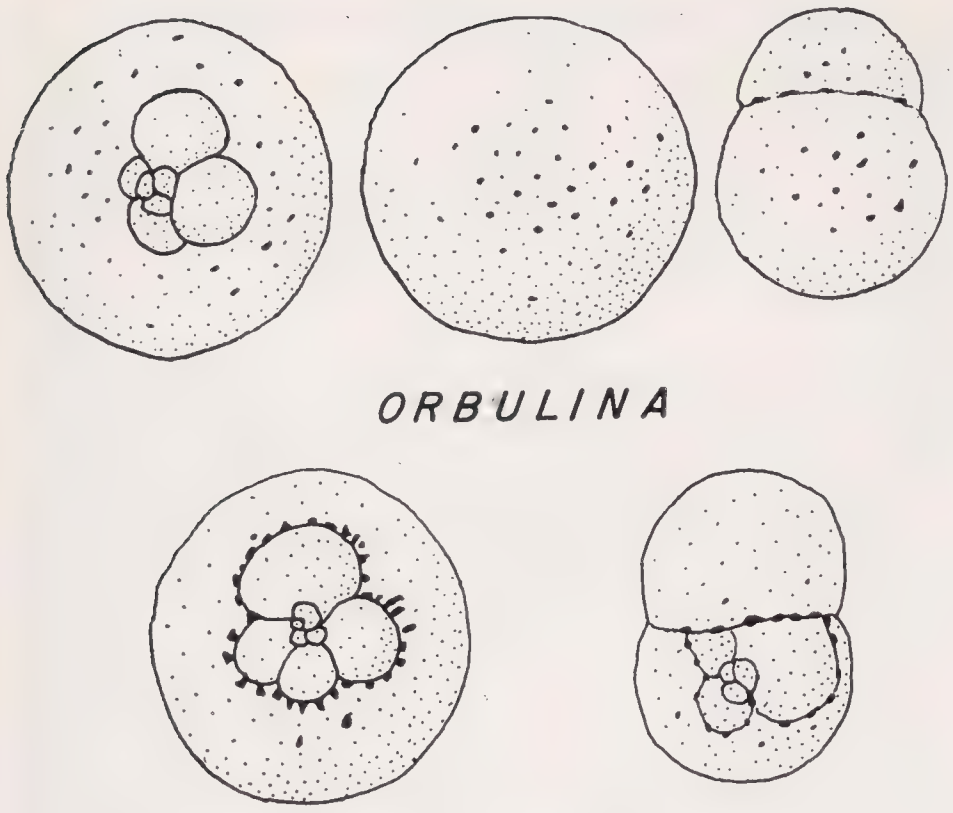

Figure 3—Variation in *Orbulina* and *Candorbulina* showing the distinguishing generic characters. The specimens of *Candorbulina* have sutural apertures; those of *Orbulina* lack sutural apertures. (Top row: After Bolli, Loeblich, and Tappan, 1957, pl. 7, figs 2-4; Lower right: UCLA hypotype 34722; Lower left: After Blow, 1956, text-fig. 2, No. 16)

CANDORBULINA UNIVERSA Jedlitschka

Pl. II, figs. 5a-7

Candorbulina universa JEDLITSCHKA, 1934, Naturf. Ver. Brünn, Verh., Brünn, Tschechoslowakei, Bd. 65 (1933), p. 21, text-figs. 1-7.

Candeina triloba JEDLITSCHKA, 1934, Naturf. Ver. Brünn, Verh., Brünn, Tschechoslowakei, Bd. 65 (1933), p. 22, text-figs. 13-18, 20.

Orbulina suturalis BRÖNNIMANN, 1951 (partim), Contr. Cushman Found. Foram. Res., v. 2, p. 135, text-fig. 2, figs. 1-2, 5-8, 10; text-fig. 3, figs. 3-7, 11, 13-14, 18; text fig. 4, figs. 2-3, 15.

Globigerinoides glomerosa glomerosa BLOW, 1956, Micropaleontology, v. 2, no. 1, p. 65, text-fig. 1, nos. 15-19; text-fig. 2, nos. 1-2. OLSSON, 1964, Jour. Paleontology, vol. 38, no. 4, p. 770.

Globigerinoides glomerosa circularis BLOW, 1956, Micropaleontology, v. 2, no. 1, p. 65, text-fig. 2, nos. 3-4.

Biorbulina bilobata (d'Orbigny). BLOW, 1956 (partim), Micropaleontology, v. 2, No. 1, p. 69, text-fig. 2, no. 16.

Test free, spherical to lobate, initially trochospiral. Chambers globular, last chamber partially to nearly completely enveloping previous globigerine chambers, 3 to 4 chambers in last globigerine whorl. Sutures distinct, depressed, radial. Wall calcareous, coarsely perforate, hispid. Aperture circular, umbilical in early globigerine stage, multiple sutural pore-like apertures or rarely multiple areal pores near sutures in final spherical chamber.

Remarks: Most specimens of this species at Newport Bay are typical (Pl. II, fig. 6) although rarely the final chamber does not completely envelop the preceding chambers, resulting in a trilobate or bilobate outline (Pl. II, fig. 5).

This species has been confused with *Orbulina universa,* which may also have protruding trochospiral whorls, because this trivial name is used in both *Candorbulina* and *Orbulina.*

Specimens showing the characters of *Globigerinoides glomerosa glomerosa* Blow, 1956, *G. glomerosa circularis* Blow and part of Blow's *Biorbulina bilobata* have been observed in single samples from both Newport Bay and Trinidad. All three forms are here placed in synonymy with *C. universa.* Blow (1956) figured specimens of each from the same samples and reported the same stratigraphic range for all. Therefore, these nominal species and subspecies are considered to be part of the single species, *Candorbulina universa,* and such varied specimens can be found in any normal population. Blow (1956) also included bilobed specimens of both *Candorbulina* and *Orbulina* in *B. bilobata* (d'Orbigny) as he recognized it. In populations of both *C. universa* and *O. universa* bilobed varieties may be present. They may be differentiated generically by the presence or absence of sutural apertures (Fig. 3) just as their normal forms are separated. *Globigerina bilobata* d'Orbigny, the type species of *Biorbulina* Blow, is a variant of *O. universa* d'Orbigny, hence *Biorbulina* is a synonym of *Orbulina.*

Candorbulina universa as defined herein apparently is restricted to the Middle Miocene. Specimens assignable to true *C. universa* were described from rocks of this age in Czechoslovakia (Jedlitschka, 1934) and have been reported elsewhere in Europe (Cushman and Dorsey, 1940), the pre-Carpathians of Russia (Subbotina, Pishvanova, and Ivanova, 1960), Ecuador (Stainforth, 1948), Trinidad (Bolli, 1957), Australia (Jenkins, 1960) and Sumatra (Le Roy, 1948). Many additional references to this species may be found in the literature, but need rechecking to determine whether *Candorbulina* or *Orbulina* is present. Brönnimann (1951) reported *C. universa* (as *O. suturalis*) from the *Globorotalia fohsi* Assemblage Zone (now believed to be Burdigalian in age) in Trinidad and was able

to recognize distinct assemblages of this form for different parts of that zone. The Newport Bay specimens resemble most closely Brönnimann's figures of specimens from the lower part of the *G. fohsi* zone (*G. fohsi barisanesis* and *G. fohsi fohsi* subzones). At Newport Bay the species occurs in sample 13 and suggest a correlation with some part of the lower *G. fohsi* zone of Trinidad.

Types: Figured hypotypes UCLA nos. 34722, 34723, 34724; 100 unfigured hypotypes UCLA no. 34725. All types from sample 13, Luisian.

Subfamily HASTIGERININAE Bolli, Loeblich and Tappan, 1957

Test trochospiral to planispiral. Chambers ovate, spherical, radially elongate, or clavate. Wall hispid (spinose) in early stages, smooth or with large spines in adult. Aperture peripheral, without supplementary apertures.

Remarks: When living, the juvenile specimens (early stages) of species of the type genus, *Hastigerina* Thomson, 1876, have long, thin spines such as are typical of the globigerinids (Parker, 1962, p. 228). For this reason the subfamily is placed in the family Globigerinidae. It may be differentiated from the Globigerininae by the lack of long, thin globigerinid spines in the adult.

Genus PROTENTELLA Lipps, gen. nov.

Type species: Protentella prolixa Lipps, sp. nov.

Test free, trochospiral in first whorl, planispiral in later stages. Chambers spherical in juvenile stage, later chambers radially elongate. Wall calcareous, smooth, finely perforate, of radially crystalline structure, septa bilamellid. Aperture basal, a low equatorial arch.

Remarks: Protentella may be differentiated from other hastigerinids and globigerinids by its planispiral test with radially elongate chambers in the later stages, and by the smooth wall texture. A few specimens have slight knobs on the chambers which may represent the bases of large spines, although because of their rare occur-

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PLATE II

(All figures: a. spiral view, b. umbilical view, c. edge view, unless otherwise noted)

Figures — Page

1. *Globigerina bulloides* d'Orbigny 116
   Hypotype (UCLA 34700). x 95. Mohnian
2. *Globigerina* cf. *G. digitata* Brady 116
   Hypotype (UCLA 34704). x 95. Luisian
3. *Globigerinoides trilobus* (Reuss) 120
   Hypotype (UCLA 34717). x 65. Luisian
4. *Globigerinoides*? sp. 120
   Figured specimen (UCLA 34720). x 95. Luisian
5. *Candorbulina universa* Jedlitschka 121
   Trilobate specimen (UCLA 34722); a. Spiral view, b. Side view; x 95. Luisian
6. *Candorbulina universa* Jedlitschka 121
   Typical specimen (UCLA 34723). x 65. Luisian
7. *Candorbulina universa* Jedlitschka 121
   Dissected specimen (UCLA 34724) showing umbilical view of inner globigerine whorls. x 95. Luisian
8. *Protentella prolixa* Lipps sp. et gen. nov. 124
   Holotype (UCLA 34726). x 95. Luisian
9. *Protentella prolixa* Lipps sp. et gen. nov. 124
   Paratype (UCLA 34727). x 135. Luisian

Figures 1, 2, 4, 5 by Jill Penkhus; others by Margaret Rogers.

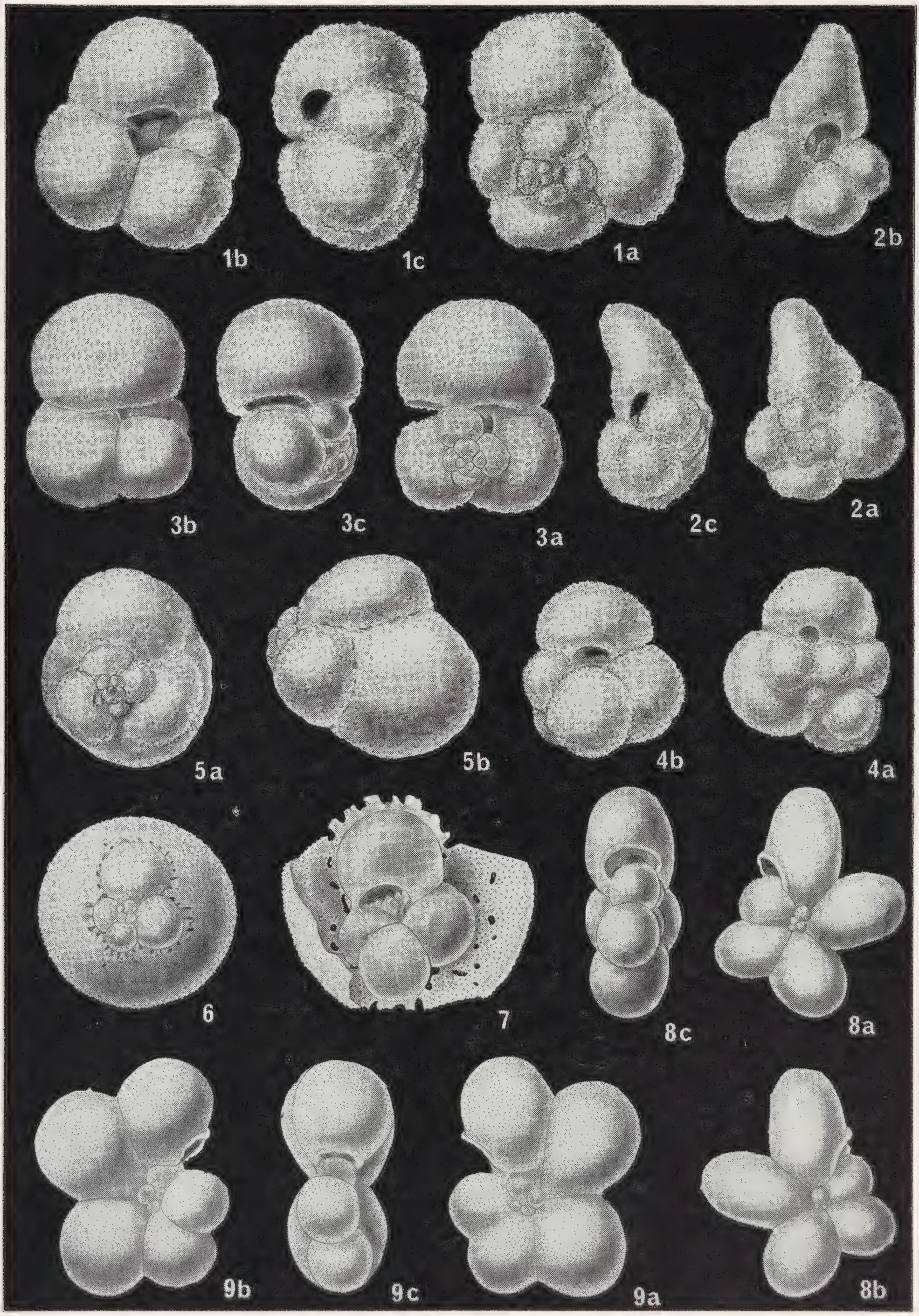

PLATE II

fence their significance could not be determined.

The generic name is from the Latin *protensus, protentus* meaning "stretched out," in reference to the typically elongate chambers of this genus +*ella,* diminutive. Gender: feminine.

PROTENTELLA PROLIXA Lipps, sp. nov.

Pl. II, figs. 8a-9c

Test free, small, planispiral, involute, biumbilicate, outline deeply lobate, periphery rounded. Chambers spherical in early whorls, becoming radially elongate in last whorl, ovate to cylindrical, five or less commonly six chambers in last whorl, nearly completely embracing previous whorl. Sutures distinct, deeply depressed, radial. Wall calcareous, smooth, finely perforate. Aperture basal, equatorial, a low to high arch embracing previous whorl, up to one-third height of final chamber, with upper margin bordered by a slightly protruding lip.

Greatest diameter of holotype .357 mm; greatest thickness .128 mm.

Remarks: This new species resembles *Hastigerinella bermudezi* Bolli, but differs in the more planispiral rather than trochospiral adult test, and the somewhat smaller size. *Protentella prolixa* is restricted to the upper part of the Luisian (samples 17 to 22).

The specific name is from the Latin *prolixus,* meaning "long, stretched out," in reference to the elongate chambers of this species.

Types: Holotype UCLA no. 34726, sample 18, figured paratype UCLA no. 34727, sample 22, 100 unfigured paratypes UCLA no. 34728 and 10 unfigured paratypes USNM no. 641566. All Luisian.

Family GLOBOROTALIIDAE Cushman, 1927

Parker (1962, p. 234) restricted this family to include only those species which are non-spinose when living. The species included by her were divided into three groups: 1.) those with imperforate keels; 2.) those without imperforate keels and with smooth walls; 3.) those without imperforate keels and with pitted walls. Parker noted that the carinate species may have developed from various noncarinate lineages, but this relation is yet to be demonstrated in most cases. The third group, however, seems less closely related to the other two. It is herein recognized as the subfamily Catapsydracinae, although some evidence indicates that it perhaps should be elevated to family status.

Subfamily GLOBOROTALIINAE Cushman, 1927

Test free, trochospiral, periphery keeled or unkeeled, chambers angular to ovate. Wall calcareous, smooth, perforate, may have secondary short, stubby spines. Aperture extraumbilical to umbilical in position.

Genus TURBOROTALIA Cushman and Bermudez, 1949

This genus, originally described as a subgenus of *Globorotalia,* is now recognized as a separate genus because it lacks a keeled periphery (see Loeblich and Tappan, 1964, p. C668).

TURBOROTALIA LATA Lipps, sp. nov.

Pl. III, figs. 2a-3c

Test free, trochospiral, about 3 whorls, planoconvex to slightly biconvex, with spiral side generally planar, umbilicus may be closed or open widely, outline slightly lobate, periphery rounded. Chambers trigonal and much inflated on umbilical side, lunate on spiral side, oval in edge view with axis of oval tilted about 45° to equatorial plane of test, last chamber may be reduced to half or less of normal chamber size. Sutures distinct, slightly depressed, curved backward, may be radial on umbilical side. Wall smooth, fine to coarsely perforate. Aperture umbilical-extraumbilical, a high rounded arch, bordered by a small lip.

Greatest diameter of holotype .234 mm; greatest thickness .162 mm.

Remarks: This species is distinguished from *Turborotalia scitula* by its more inflated chambers and biconvex test. It is most similar to *Globorotalia hirsuta* (d'Orbigny) which possesses a keeled periphery, although some specimens in certain populations may be unkeeled (Parker, 1962, p. 237). No carinate specimens were found with *T. lata. Turborotalia lata* occurs in most Luisian samples and is especially abundant in sample 2.

Types: Holotype UCLA no. 34729; figured paratype UCLA no. 34730; 100 unfigured paratypes UCLA no. 34731; 10 unfigured paratypes USNM no. 641567. All types from sample 2, Luisian.

TURBOROTALIA MAYERI (Cushman and Ellisor)

Pl. III, figs. 4a-5c

Globorotalia mayeri CUSHMAN and ELLISOR, 1939, Contr., Cushman Lab. Foram. Res., v. 15, pt. 1, p. 11, pl. 2, figs. 4a-c.

Test free, trochospiral, biconvex to flat-

tened on spiral side, 2½ whorls, periphery rounded, outline slightly lobate. Chambers inflated, trigonal in umbilical view, ovate to rectangular in spiral view, broadly rounded in edge view. Sutures distinct, depressed slightly, curved back on spiral side, recurved on umbilical side. Wall calcareous, smooth, coarsely perforate. Aperture a wide extraumbilical arch, bordered by small protruding lip.

Remarks: The specimens from Newport Bay are smaller than the holotype of *T. mayeri* (Pl. III, figs. 4a-c) with which they were compared, but do not differ significantly in other respects. Some specimens are aberrant and the last few chambers may show irregular coiling, being somewhat deflected to the umbilical side. Both right and left coiling specimens are present but the specimens are too rare to determine a significant coiling ratio. The species occurs only in the Mohnian at Newport Bay, although elsewhere in the world it has a long stratigraphic range, from the Aquitanian to the Tortonian (see Bandy, 1964b, text-fig. 6). Therefore, it should have occurred throughout the Newport Bay section had the ecologic conditions been suitable.

Types: Figured hypotype UCLA no. 34732; 5 unfigured hypotypes UCLA no. 34733, sample 34, Mohnian.

Turborotalia scitula (Brady)

Pl. III, figs. 1a-c

Pulvinulina scitula Brady, 1882, Roy. Soc. Edinburgh, Proc., v. 11 (1880-1882), no. 111, p. 716.

Test free, trochospiral, nearly 3 whorls, flattened to convex on spiral side, convex on umbilical side except for slight depression at umbilicus, umbilicus open, small, deep, outline slightly lobate, periphery subacute. Chambers lunate in spiral view, triangular in umbilical view, rhomboid in edge view, commonly increasing rapidly in height in the final whorl, inflated on umbilical side near base, tapering toward periphery, slightly recurved inward above aperture in edge view, flattened on spiral side, overlapping about one-third to one-half of previous chamber; commonly 5 chambers in last whorl. Sutures distinct, curved back on spiral side, radial or slightly curved back on umbilical side. Wall smooth, finely perforate. Aperture umbilical-extraumbilical, basal, a low arch with slight lip.

Remarks: Specimens from Newport Bay are nearly identical with the lectotype selected by Banner and Blow (1960). Because of variation occurring in chamber height and test thickness, some specimens could be allocated to one of the subspecies described by Blow (1959), but since they all occur together, they probably represent individual variants of the same population.

This species was found in most of the samples studied, but never in abundance. From all the samples, a total of several hundred specimens were studied.

Type: Figured hypotype UCLA no. 34734, sample 21, Luisian.

Subfamily Catapsydracinae Bolli, Loeblich and Tappan, 1957

Test trochospiral, chambers spherical to ovate or angular, with or without apertural bullae. Primary aperture umbilical to extraumbilical in position, may have secondary apertures or infralaminal accessory apertures. Wall calcareous, surface coarsely pitted, may have short, stubby spines, non-spinose when living.

Remarks: Bolli, Loeblich and Tappan (1957, p. 36) erected this subfamily to include forms with apertural bullae. However, bullae have developed independently in many different lineages and are considered taxonomically unimportant at the suprageneric level. The type genus, *Catapsydrax* Bolli, Loeblich and Tappan, 1957, has a coarsely pitted wall identical with that of *Globoquadrina,* which is non-spinose when living (Parker, 1962, p. 240). *Catapsydrax* probably was also non-spinose when living. The non-spinose, coarsely pitted wall texture distinguishes this subfamily from all other groups of the Globigerinidae and Globorotaliidae.

Genus Globoquadrina Finlay, 1947

This genus is placed in the Catapsydracinae because of the coarsely pitted wall and non-spinose condition in life. It is very closely related to *Catapsydrax,* differing primarily in lacking an apertural bulla.

Globoquadrina larmeui Akers

Pl. III, figs. 6a-7c

Globoquadrina larmeui Akers, 1955, Jour. Paleontology, v. 29, no. 4, p. 661, pl. 65, figs. 4a-c.

Test free, small to medium in size, trochospiral, spiral side slightly convex, umbilical side convex, periphery broadly rounded, outline lobate. Chambers 4 or 5 in last whorl, lunate in spiral view, rounded in other views, increasing gradually in size with growth, occasionally with small terminal chamber. Sutures distinct, radial, depressed. Wall smooth with large, deep pits. Aperture a low arch, extraumbilical to umbilical in small specimens, umbilical in large ones, with ragged margin or projecting tooth.

Remarks: Specimens similar to the original figures of this species occur in sample 11. These specimens intergrade with forms with large umbilical apertures and more numerous chambers in the final whorl.

Types: Figured hypotypes UCLA nos. 34737 and 34738; 100 unfigured hypotypes UCLA no. 34739; sample 11, Luisian.

GLOBOQUADRINA VENEZUELANA (Hedberg)

Pl. IV, figs. 1a-c

Globigerina venezuelana HEDBERG, 1937, Jour. Paleontology, v. 11, no. 8, p. 681, pl. 92, figs. 7a-b.

Test free, low trochospire of 2½ whorls, outline lobate and quadrate, periphery rounded to slightly truncate. Four or less commonly three chambers in last whorl, inflated, flattened slightly on periphery, all visible on spiral side, those of last whorl nearly overlapping previous whorls. Sutures distinct, deeply depressed, radial on both sides. Wall calcareous, exterior rough and pitted with pores in bottom of each pit, interior smooth with small perforations. Apertures square or angular, umbilical in position, with umbilical teeth and coarse, short, needle-like spines in apertural area.

Remarks: Typical specimens of this species occur in samples 4 to 16, but are most abundant in samples 13 to 16, of Luisian age. The species has a long range through the later Tertiary in other parts of the world, and it is probable that it is more widely distributed in California.

Types: Figured hypotype UCLA no. 34735, sample 16, and 200 unfigured hypotypes UCLA no. 34736, sample 13, Luisian.

Genus GLOBOROTALOIDES Bolli, 1957

Bolli (1957, p. 117) erected this genus primarily on the basis of the bulla-like last chamber of some specimens. This character was not considered to be of generic importance by Loeblich and Tappan (1964, p. C671), who retained the genus on the basis of the globular chamber form. Parker (1962, p. 240) suggested that it was a synonym of *Globoquadrina.* The holotype of the type species, *Globorotaloides variabilis* Bolli, has a small bulla-like final chamber, which gives it a superficial resemblance to *Globoquadrina.* Some specimens of species that correctly should be assigned to *Globorotaloides* have a slight projecting apertural lip, which is believed by Parker to represent the apertural tooth of *Globoquadrina.* However, the globular chambers, low trochospiral test, generally extraumbilical aperture, the characters of the apertural lip, and the pitted surface distinguish *Globorotaloides* from all previously described genera.

PLATE III

(All figures: a. spiral view, b. umbilical view, c. edge view, unless otherwise noted)

Figures — Page

1. *Turborotalia scitula* (Brady) ---- 125
   Hypotype (UCLA 34734). x 135. Luisian
2. *Turborotalia lata* Lipps sp. nov. ---- 124
   Paratype (UCLA 34730) with very small final chamber. x 140. Luisian
3. *Turborotalia lata* Lipps sp. nov. ---- 124
   Holotype (UCLA 34729). x 190. Luisian
4. *Turborotalia mayeri* (Cushman and Ellisor) ---- 124
   Holotype (USNM Cushman Coll. no. 25236), refigured for comparison with California specimen. x 90. Miocene, Louisiana
5. *Turborotalia mayeri* (Cushman and Ellisor) ---- 124
   Hypotype (UCLA 34732). x 180. Mohnian
6. *Globoquadrina larmeui* Akers ---- 125
   Hypotype (UCLA 34737) with wide, open aperture. x 95. Luisian
7. *Globoquadrina larmeui* Akers ---- 125
   Hypotype (UCLA 34738). x 95. Luisian

Figures 1, 2, 3, 6 by Margaret Rogers; 4, 5 by Helen Loeblich; 7 by Jill Penkus.

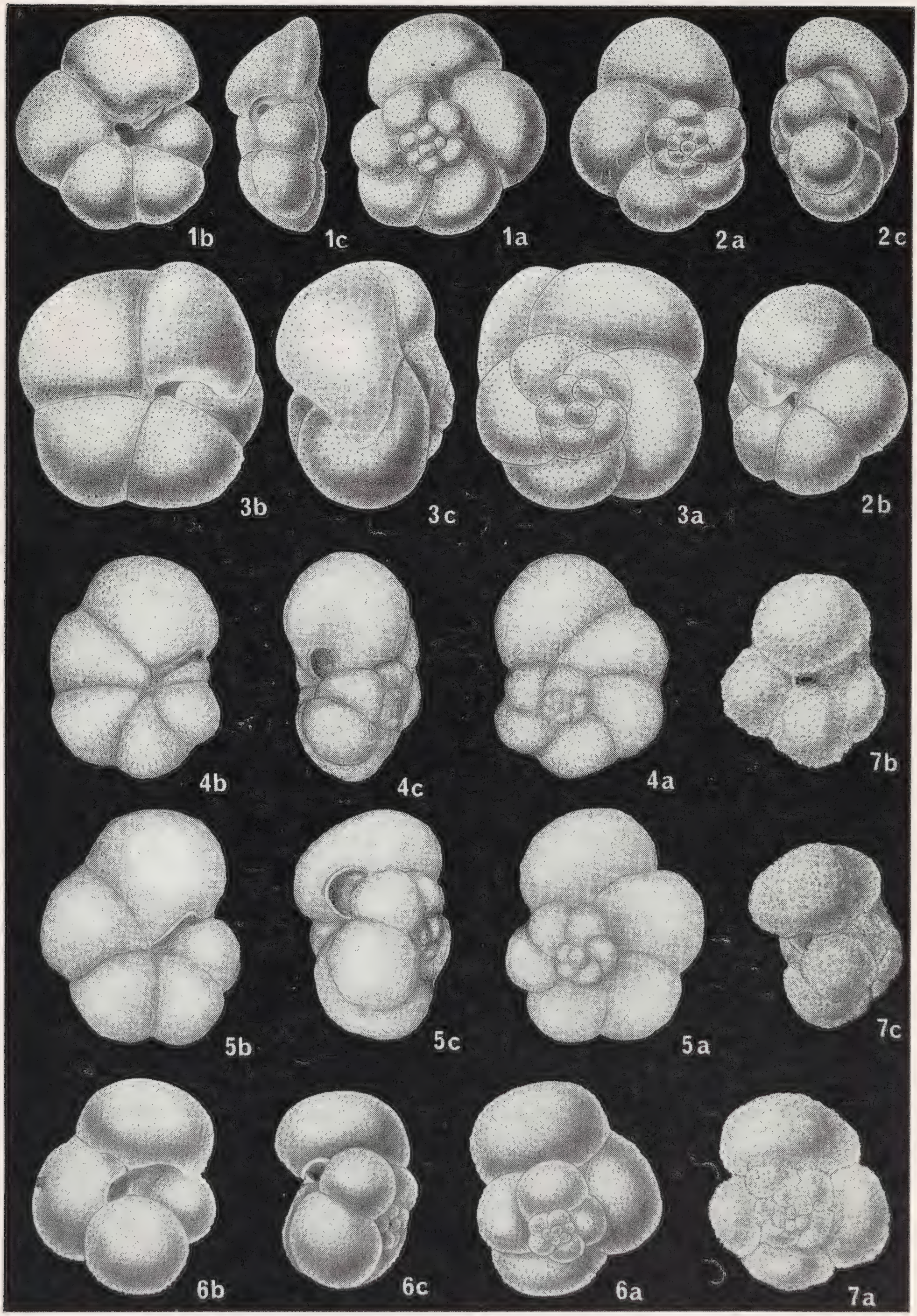

PLATE III

Globoquadrina has a higher trochospire, larger ovate or quadrate chambers, an umbilical aperture and well-formed apertural teeth. The present genus is differentiated from *Catapsydrax* by the lack of umbilical bullae.

This genus is placed in the Catapsydracinae on the basis of its coarsely pitted surface texture.

GLOBOROTALOIDES TREMA Lipps, sp. nov.

Pl. IV, figs. 3a-c

Test free, small, trochospiral about 2½ whorls, flat to slightly convex on spiral side, flattened to concave on umbilical side, umbilicus wide, deep, outline deeply lobate, periphery rounded. Chambers spherical to slightly lunate, increasing evenly in size with growth, 6 to 7 in last whorl, last chambers of large specimens tend to shift onto the umbilical side of test. Sutures radial, depressed, distinct. Wall calcareous, surface with numerous small pits Aperture extraumbilical, a low, semicircular arch, basal in position, visible only in edge view, with small apertural lip bordering upper edge.

Greatest diameter of holotype .179 mm; greatest thickness .080 mm.

Remarks: Specimens of this new species were compared to the holotype and paratypes of *Globorotaloides suteri* Bolli and *G. variabilis* Bolli. The holotype and four paratypes of *G. suteri* were found to be identical to specimens of *G. hexagona* (Natland) from Recent sediments off southern California. *Globorotaloides hexagona* was originally referred to *Globigerina* by Natland (1938) and subsequently transferred to *Globoquadrina* by Parker (1962). It is here placed in *Globorotaloides* because it has all the distinguishing characters of that genus. *Globorotaloides trema* is differentiated from *G. hexagona* and *G. variabilis* by its much smaller size (generally less than 50%), more numerous chambers in the last whorl (6 to 7 rather than 5 to 6), less inflated chambers, flatter test, smaller diameter of the surface pits, and an apparent lack of terminal bullae-like chambers. In addition it is separated from *G. variabilis* by its nearly spherical chambers and straight sutures.

The specific name is from the Greek *trema, trematos,* meaning "hole," in reference to the deep umbilicus of the new species.

Types: Holotype UCLA no. 34740; 100 unfigured paratypes UCLA no. 34741; 10 unfigured paratypes USNM no. 641568; all from sample 18, Luisian.

Subfamily GLOBIGERINITINAE-Bermudez, 1961

Test trochospiral. Chambers ovate to spherical, last chamber may be modified to cover umbilical area, or test may have apertural bullae. Primary aperture umbilical, secondary apertures sutural or infralaminal. Wall calcareous, perforate, smooth or finely hispid, non-spinose when living.

Remarks: This subfamily is here recognized to contain those planktonic foraminifera with smooth and finely hispid wall textures, globular or ovate chambers, and with modified last chambers or bullae. Parker (1962, p. 244) did not attempt to classify these forms on the basis of surface texture because they show affinities to both the Globigerinidae and the Globorotaliidae. These foraminifera are non-spinose when living, hence appear to be more closely related to the Globorotaliinae, as previously noted by Parker. They are here regarded as a separate subfamily of the Globorotaliidae.

Bermudez (1961, p. 1.261) erected this subfamily as a substitute name for the Catapsydracinae whose type genus, *Catapsydrax,* he believed to be synonymous with *Globigerinita.* However, on the basis of surface texture, as well as other morphologic features, the two genera are not considered to be closely related. The subfamilies based on them are therefore not regarded as synonymous, and the name Globigerinitinae is available for the subfamily group which includes *Globigerinita.*

Genus GLOBIGERINITA Brönnimann, 1951

Parker (1962, p. 246) redefined this genus to include those species with smooth or finely hispid walls which are non-spinose when living and which have a modified final chamber or bulla over the apertures. Loeblich and Tappan (1957) erected *Tinophodella* to contain those species with a separate, distinct plate covering the aperture, hence unlike the holotype of the type species of *Globigerinita.* Parker (1962, p. 248-249) also noted discrepancies in the distributional pattern of the forms with modified terminal chambers and those with a plate-like bulla. It appears advisable to retain *Tinophodella* for those foraminifera with plate-like bullae closely covering the aperture until the distributions and biology of the two types are more completely known. *Tinophodella,* although placed in the Globigerinitinae, is excluded from true *Globig-*

erinita. Species of so-called *Globigerinita* with low trochospiral whorls and modified last chambers probably should be placed in *Eoglobigerina.*

GLOBIGERINITA UVULA (Ehrenberg)

Pl. IV, figs. 2a-c

Pylodexia uvula EHRENBERG, 1861, K. Preuss. Akad. Wiss. Berlin, Monatsber., p. 276, 277, 308.

Test free, highly trochospiral, trigonal in side view, quadrate in umbilical view, lobate, periphery rounded. Chambers spherical, 4 in last whorl. Sutures radial, distinct, depressed. Wall thin, finely hispid, perforate. Aperture umbilical, a low arch, may have a small bulla-like inflated chamber and small slit-like accessory apertures.

Remarks: The synonymy and discussion of this species by Parker (1962, p. 252) is followed herein. She noted the possible synonymy of *Globigerina juvenilis* Bolli. Forms resembling this species were found in Luisian strata although it is not possible to distinguish the small specimens from tiny *Eoglobigerina minutissima.* In the Mohnian there are rare specimens resembling *Globigerinoides minuta* Natland, a junior synonym of *Globigerinita uvula* according to Parker.

Type: Figured hypotype UCLA no. 34742, sample 34, Mohnian.

Genus EOGLOBIGERINA Morozova, 1959

Globigerina (Eoglobigerina) MOROZOVA, 1959, Akad. Nauk SSSR, Doklady, v. 124, no. 5, p. 1115.

Type species: Globigerina (Eoglobigerina) eobulloides Morozova, 1959. Fixed by original designation.

Test free, small, trochospiral, periphery rounded. Chambers spherical to quadrate, final chamber may be modified with umbilical projection covering aperture and umbilicus. Wall smooth to very finely hispid. Aperture umbilical to extraumbilical, may be covered or uncovered.

Remarks: Eoglobigerina was described by Morozova (1959) to contain smooth-walled, globigerinid-like species from Paleocene sediments in Russia. Loeblich and Tappan (1964, p. C671) regarded it as a synonym of *Globorotaloides.* However these genera can be clearly distinguished on the basis of wall texture, chamber shape and test proportions.

Eoglobigerina is recognized herein by its smooth surface texture, nearly globular chambers and the umbilical extension of the final chamber in some adult specimens.

EOGLOBIGERINA MINUTISSIMA (Bolli)

Pl. IV, fig. 4a-6c

Globorotalia minutissima BOLLI, 1927, U. S. Natl. Mus. Bull. 215, p. 119, pl. 29, figs. 1a-c.

Test free, small, trochospiral, spire flat to high, 2½ to 3½ whorls, umbilical side concave in center, umbilicus most commonly covered, outline slightly to deeply lobate, periphery broadly rounded. Chambers spherical to ovate, inflated, increasing evenly in size, 5 to 6 in last whorl, last chamber may be reduced or bulla-like and cover aperture and umbilicus. Sutures radial, distinct, depressed. Wall smooth to finely hispid. Aperture umbilical to extraumbilical, a low arch, bordered by lip or projection of last chamber which may also cover umbilicus.

Remarks: Much variation occurs in this species throughout the section at Newport Bay (see Pl. IV, figs. 4-6). Many specimens are identical to topotypes from Trinidad and these grade into larger high-spired varieties.

This species is placed in *Eoglobigerina* rather than *Globorotalia* because of its spherical to oval chambers and modified terminal chambers.

Types: Figured hypotypes UCLA nos. 34743, 34744, 34745, from samples 1, 2, and 18 respectively; 200 unfigured hypotypes each, UCLA nos. 34746, 34747, 34748, from samples 1, 16, and 34, respectively.

EOGLOBIGERINA OPERTA Lipps, sp. nov.

Pl. IV, figs. 7a-c

Test free, trochospiral, about 2½ whorls, convex on spiral side, slightly concave to convex on umbilical side, umbilicus small, deep when open, or may be covered, outline lobulate, circular in small specimens, quadrate in large ones, edges broadly rounded on umbilical side, more sharply rounded on spiral side. Chambers inflated, spherical in early stages, becoming elongate tangentially, chambers larger where adjacent to earlier chambers, then tapering and becoming smaller toward aperture, 4 to 5 in last whorl, latest chambers tend to coil onto umbilical side of test, final chamber commonly reduced and covering umbilicus. Sutures radial, depressed, more deeply incised on umbilical side. Wall smooth, very finely perforate. Aperture extraumbilical, semicircular, with small protruding lip, commonly covered by small modified terminal chamber with an umbilical-extraumbilical opening.

Greatest diameter of holotype .204 mm; greatest thickness .136 mm.

Remarks: This new species is differentiated from other species by its tangentially

elongate, tapering chambers. *Globorotalia acostaensis* Blow, 1959, and *G. birnageae* Blow, 1959, are similar to *E. operta* but the chambers are not as wide in the former. The generic assignment of Blow's species could not be determined from the original descriptions and illustrations, and they may not be related to *Eoglobigerina.*

Eoglobigerina operta occurs near the top of the section studied, in Mohnian sample 34.

The specific name is from the Latin *opertus,* meaning "cover, hide," in reference to the covered or hidden aperture and umbilicus.

Types: Holotype UCLA no. 34749; 100 unfigured paratypes UCLA no. 34750; 10 unfigured paratypes USNM no. 641569; all from sample 34, Mohnian.

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Plate IV

(All figures: a. spiral view, b. umbilical view, c. edge view, unless otherwise noted)

Figures — Page

1. *Globoquadrina venezuelana* (Hedberg) ---- 126
   Hypotype (UCLA 34735). x 70. Luisian
2. *Globigerinita uvula* (Ehrenberg) ---- 129
   Hypotype (UCLA 34742). x 130. Mohnian
3. *Globorotaloides trema* Lipps sp. nov. ---- 128
   Holotype (UCLA 34740). x 190. Luisian
4. *Eoglobigerina minutissima* (Bolli) ---- 129
   Small specimen (UCLA 34743) without apertural lip. x 190. Luisian
5. *Eoglobigerina minutissima* (Bolli) ---- 129
   Larger, high spired specimen (UCLA 34745). x 190. Luisian
6. *Eoglobigerina minutissima* (Bolli) ---- 129
   Hypotype (UCLA 34744). x 190. Luisian
7. *Eoglobigerina operta* Lipps sp. nov. ---- 129
   Holotype (UCLA 34749). x 190. Mohnian

Figure 2 by Jill Penkhus; others by Margaret Rogers.

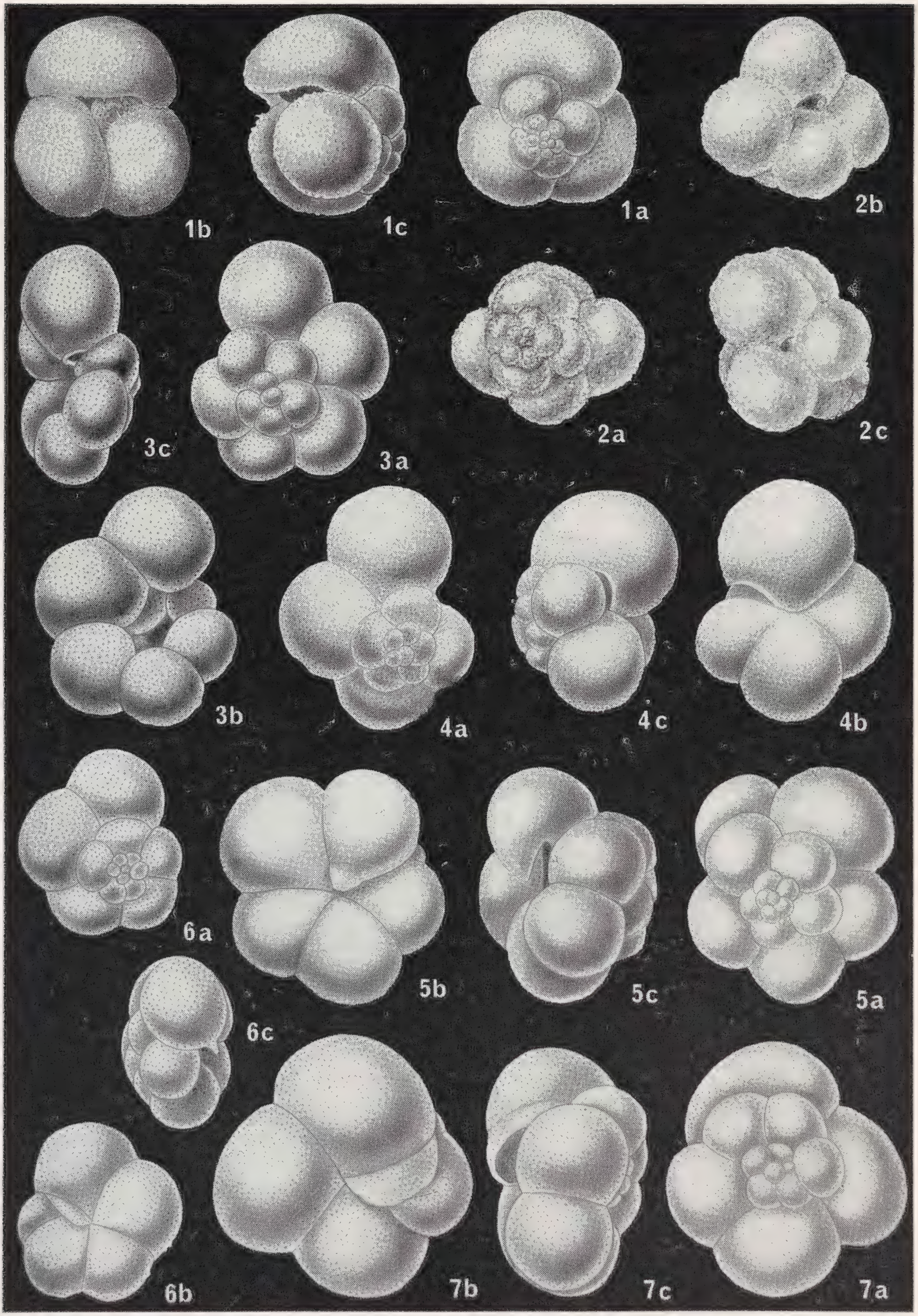

PLATE IV

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MARGARITARIIDAE, NEW FAMILY (PELECYPODA) AND DESCRIPTION OF TWO NEW SPECIES

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CONTENTS

Page

ABSTRACT 135
I. INTRODUCTION 135
II. SYSTEMATIC DESCRIPTIONS 136
LITERATURE CITED 141
PLATE 1 139

ABSTRACT

The new family Margaritariidae is proposed for the genus *Margaritaria* Conrad, 1849, of which the type, and previously only known species, is *Pholadomya abrupta* Conrad, 1832. This species, described from the upper Miocene deposits at Yorktown, Va., has been reported from southern Maryland to South Carolina in beds of middle and (mainly) upper Miocene age. The southern limit of its range is here extended to Collier County, Florida. Two new species are described: *M. inexpectata* from the upper Eocene Moodys Branch Marl, near Montgomery, Louisiana, and *M. gardnerae* from the Miocene Shoal River Formation of the Alum Bluff Group in Walton County, Florida.

I. INTRODUCTION

In 1832, Conrad described and figured (p. 26, pl. 12) a species from "York-town, Virginia, Upper Tertiary" which he denominated *Pholadomya abrupta.* Subsequently Deshayes (1835, p. 66), Sowerby (1840, p. 4), and others referred this species to the genus *Panopaea* [= *Panopea* Menard de la Groye, 1807]. Conrad commented upon this reassignment in 1849, and (p. 214) provisionally proposed the new generic name *Margaritaria.* In 1863 (p. 572) he treated *Margaritaria* as a subgenus of *Pholadomya.*

In the more than 130 years that have elapsed since the original description, Conrad's species has proved to be more or less widely distributed in the middle and upper Miocene deposits from southern Maryland to South Carolina. It is, however, never abundantly represented and due to the internally nacreous shell material, is fragile and usually is poorly preserved. But, during this same interval of time, no other species has been described that is referable to the genus *Margaritaria.*

It was with some surprise, therefore, that a second species was found in the Shoal River fauna at an outcrop near the famous "Shell Bluff" locality on Shoal River in western Florida. Even more unexpected was the recovery of yet a third species in the Moodys Branch Marl (Jacksonian, upper Eocene) at Creole Bluff on Red River near Montgomery, Grant Parish, Louisiana. This locality is widely known in the literature as "Montgomery Landing." Although each of the new species is represented by a single imperfect specimen, their obvious rarity and the extension of both the known geologic and geographic range of the genus justifies

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their description. In addition, it is now possible to record the occurrence of *Margaritaria abrupta* in the Tamiami Formation of peninsular Florida. A well-preserved mould of the interior of a right valve accompanied by a broken mould of the left valve was collected by Mr. Druid Wilson of the United States Geological Survey from the lime pits at Sunniland in Collier County, Florida.

II. Systematic Descriptions

Family Margaritariidae Vokes, new family

Genus Margaritaria Conrad, 1849

Margaritaria Conrad, 1849, Acad. Nat. Sci., Philad., Jour., **1** (4), p. 214; (as *Margiritaria* in index). Conrad, 1863, Acad. Nat. Sci., Philad., Proc., **14**, p. 572.

Actinomya Mayer, 1870, Vierteljahrschr. naturf. Ges. Zürich, **15**, pp. 45, 59.

Type species, by monotypy, *Pholadomya abrupta* Conrad, 1832.

Conrad's introduction of the generic name was not accompanied by a diagnosis, and so far as I am aware, the lack has not been met by any author. Since the genus previously has been monotypic, the description of the species has served also as a generic diagnosis. The two new species presently added are, on the whole, exceedingly similar to the previously known form, and we may here use the major part of Dall's description of *M. abrupta* (1903, p. 1533) as a diagnosis of the genus:

> "Shell nacreous, subsolenoid in form, sparsely radially sculptured; rounded and slightly gaping in front, abruptly truncate and widely gaping behind; the beaks submedial, low, ligament external, elongate, on strong nymphs; Hingeplate continuous, edentulous, narrow; muscular impressions distinct; pallial line wide, somewhat irregular, . . . with a short angular sinus, at the posterior lower angle of which there is a rather large, strong scar, as if the mantle had had here a specialized area of attachment to the shell, . . . The surface when unworn is more or less granular and resembles that of *Thracia;* the interior is brilliantly pearly."

Systematic Position: There has been uncertainty regarding the systematic position of this group ever since Conrad first described the type species as *Pholadomya abrupta.* That author failed to mention the nacreous character of the shell, possibly assuming that his assignment to *Pholadomya,* a genus characterized by such structure, implied the possession of the nacreous shell in his species. This implication was apparently not perceived by Deshayes and other European workers (see above) who referred the species to *"Panopaea,"* a rather logical assignment in the light of the actual description and rather poor figure that accompanied it. The nacreous shell and the fact that the hinge is edentulous were first mentioned by Conrad in 1849 when he proposed the generic name *Margaritaria.* Conrad's statement follows:

> "This shell which Deshayes referred to *Panopea,* has a highly perlaceous substance, and is destitute of cardinal teeth. The nacre, and different form of the muscular impressions, appear to me sufficient to exclude it from *Glycimeris,* Lam. [1801, 126 (*non* 1799) = *Crytodaria* Reuss, 1801, 351], to which it approaches nearer than to *Panopea,* Aldrov."
>
> "If this Miocene fossil is inadmissable in the genus *Pholadomya,* I propose a new generic name, *Margaritaria.*"

Subsequent authors have either followed Conrad's earlier reference of his species to *Pholadomya* (Tuomey & Holmes, 1856; Emmons, 1858) or have accepted the genus *Margaritaria* (Meek, 1864; Dall, 1903; Glenn, 1904; Miller, 1912). Meek placed *Margaritaria* in the Anatinidae; both Dall and Glenn referred it to the family Pholadomyacidae, although Dall (1903, p. 1533) did so with much doubt, stating:

> "Its relations are certainly most puzzling. I was strongly tempted to place it near *Lyonsia,* but the arrangement of the ligament is more like that of *Thracia* and there is nothing to suggest the presence of a lithodesma. Its sculpture and nacre are opposed to affiliation with *Panopea,* even if we disregard the pallial sinus, but there is something in the aspect of it which recalls *Allogramma.*"

The reference to the pallial sinus in the above quotation is a reflection of Dall's uncertainty as to the nature of the pallial line in the posterior area. He stated:

> " . . . pallial line wide, somewhat irregular, sometimes apparently entire, sometimes with a short angular sinus, at the posterior lower angle of which there is a rather large, strong scar, as if the mantle had had here a specialized area of attachment to the shell. This last arrangement occurs in one specimen only, and it is possibly pathological."

I have examined the representatives of the species in the collection of the United States National Museum, including specimens from

all localities mentioned by Dall (1903, p. 1533) that had not been previously reported in the literature.[1]

Among those specimens apparently available to Dall is a left valve from Suffolk, Virginia, (USNM 146214) slightly broken antero-ventrally, which reveals the pallial sinus and scar described and is probably the "one specimen" referred to by him. There is, in addition, a right valve from Yorktown, Virginia, (USNM 498692) in which the interior is not as well preserved as in the Suffolk individual but in which the presence of a small pallial sinus can be noted. All other specimens in collections that were apparently available at the time when Dall prepared his description are incomplete or in some cases fragmentary (*i.e.,* those from Petersburg, Virginia). Because the posterior portion of the valve is thinner than the anterior, (a condition noted by Conrad in his original description) it is usually the posterior end of the valves that has been lost and the nature of the pallial sinus—including its presence or absence—cannot be observed with certainty. There is nothing in the collection that would serve to indicate the basis for Dall's statement that the pallial line was "sometimes apparently entire."

The specimen figured in the present report, from a locality one mile west of Suffolk, Virginia, is the best preserved interior that I have been able to study, and the pallial sinus, as well as the peculiar ventrally situated muscle scar, is well displayed. Another specimen, in the collection of Mr. William Rice of Hampton, Virginia, (from his marl pits in the outskirts of that city) also revealed well the presence of the sinus and accessory scar, as does, though somewhat indistinctly, the mould of the left valve from the Tamiami Formation, mentioned above. Thus not a single specimen, available for my examination and in which the posterior portion of the pallial line could be observed, has lacked the sinus. It now seems clear that its presence is characteristic of the genus and is not to be construed as representing a pathologic feature.

Thus, in all essentials, including the general shell outline, the anterior and (much wider) posterior gaping of the shell, the broad and irregular pallial line, and the presence of a small pallial sinus, *Margaritaria* agrees with the deeper burrowing members of the family Hiatellidae, especially *Panopea* Menard, 1807, *Panomya* Gray, 1857, and *Cyrtodaria* Reuss, 1801. Both of the former genera are distinguished by the presence of a small conical cardinal tooth in each valve; *Cyrtodaria,* while also edentulous, differs in details of shape including the possession of slightly twisted valves, and lacks radial ornamentation. None of these, or any of the other genera referred to this family, have the nacreous shell of *Margaritaria.* I am of the opinion that the similarities between the present genus and those of the deeper burrowing hiatellids are of adaptive significance and point to a similar ecologic habit by *Margaritaria* rather than indicating systematic relationship.

It seems most probable that *Margaritaria* represents a deep burrowing genus that evolved from a nacreous-shelled ancestral form. As noted by Dall (1903, p. 1533) there is a suggestion of *Lyonsia* in the general aspect, but the valves are not subequal in size, the arrangement of the ligament differs, "and there is nothing to suggest the presence of a lithodesma." *Thracia,* also mentioned by Dall, has a non-nacreous cellulo-crystalline shell and thus seems to be eliminated as a possible ancestor. The subnacreous inequivalved representatives of the genus *Periploma* Schumacher, 1817, while edentulous, possess an internal ligament that is supported on well-developed chondrophores, structures that are wholly absent in *Margaritaria.*

Recent species of the genus *Pholadomya,* with which the type species of *Margaritaria* originally was associated by Conrad, agree with it in possessing a thin shell that is nacreous internally and cellulo-crystalline externally. The shell is much more produced posteriorly than anteriorly and has a granular surface (see Stenzel, Krause and Twining, 1957, pl. 18, figs. 13-15) with radial ornamentation. Both *Pholadomya* and *Margaritaria* have shells that gape posteriorly

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[1] Dall's faunal list is clearly a composite one based in part on specimens and in part on the literature. Thus, there are specimens from Petersburg, Yorktown, Suffolk, and Grove Wharf, Virginia; from Natural Well, near Magnolia, North Carolina, and from Darling, South Carolina. The reference to Edgecomb County, North Carolina, is from Emmons (1858, p. 300), and those to Sumter, Smith's, and Goose Creek, South Carolina, are from Tuomey and Holmes (1856, p. 101).

and anteriorly, those of *Pholadomya* being proportionately less generous than in *Margaritaria,* and both have a similar ligamental nymph. Other features, however, reveal striking differences between the two genera. *Pholadomya* has prominent, inflated umbones, an obscure, rather weakly developed lamellar tooth in each valve, and a much more ample pallial sinus, which with the pallial line is but weakly impressed in the shell structure.

However, the Tertiary and Recent species of *Pholadomya* appear to represent the surviving relics of a geologically ancient lineage that had undergone a striking evolutionary proliferation during the Mesozoic era. Many of the differing generic manifestations of this lineage are known almost solely from internal or external moulds, a circumstance that suggests a fragile, probably at least partially nacreous, shell substance. Certain of these, as for example *Myopholas* Douvillé, 1907 (type, by original designation, *Pholadomya multicostata* Agassiz) a Middle Jurassic to Lower Cretaceous genus, appear to represent somewhat more suitable progenitors for *Margaritaria* but are yet too imperfectly known to permit any certain conclusions.

At the present time, therefore, there appears no alternative but to regard the genus *Margaritaria* as the monotypic representative of a new family, Margaritariidae, which is provisionally considered a member of the superfamily Pholadomyacea.

MARGARITARIA ABRUPTA (Conrad)

Pl. 1, figs. 1-3

Pholadomya abrupta CONRAD, 1832, Foss. Shells Tert. formations N. Amer., **1** (2), p. 26, pl. 12 (2 figs.); CONRAD, 1838, Foss. Medial Tert., U. S., (1), p. 3, pl. 1, fig. 4; CONRAD, 1843, Proc. Acad. Nat. Sci., Philad., **1**, p. 329; CONRAD, 1849, Jour. Acad. Nat. Sci., Philad., **1**, errata; TUOMEY and HOLMES, 1857, Pleiocene Foss. S. Car., p. 101, pl. 22, fig. 2; EMMONS, 1858, Rept. N. Car., Geol. Surv., Agric. East. counties, p. 300, text fig. 231.

Panopaea abrupta Conrad. DESHAYES, 1835, Anim. sans Vert., (ed. 2), **6**; SOWERBY, 1840, Min. Conch., Gr. Brit., **7** (whole no. 107, p. 4; VALENCIENNES, 1840, Arch. du Mus. d'Hist. Nat., Paris, **1**, p. 36.

Pholadomya (Margaritaria) abrupta CONRAD, 1863, Proc. Acad. Nat. Sci., Philad., **14**, p. 572.

Margaritaria abrupta Conrad. MEEK, 1864, Smithsonian Misc. Colln., no. 183, p. 12; DALL, 1903, Trans. Wagner Free Inst. Sci., Philad., **3** (6), p. 1532; GLENN, 1904, Mollusca, Pelecypoda, *in* W. B. Clark, *et al.:* Miocene, Maryland Geol. Surv., p. 361, pl. 95, figs. 5, 6; MILLER, 1912, *in* W. B. Clark, *et al.:* North Carolina Geol. and Econ. Surv., **3**, Coastal Plain, pt. 1, pp. 205, 243.

Actinomya abrupta Conr. *(Pholadom.).* MAYER, 1870, Vierteljahrschr. naturf. Ges. Zürich, **15**, pp. 45, 59.

Figured Hypotype, U.S.N.M. 644667, Length (left valve), 91.5 mm; Height, 52 mm; Diameter (paired valves) 29.2 mm adjacent to umbos where shell is partially exfoliated. Apparently would have been about 31 mm near the posterior end of the valves. Upper Miocene, Yorktown Formation, Zone 2 (?), one mile west of Suffolk, Nansemond County, Virginia.

The characteristics of the type species of the genus *Margaritaria,* have been rather thoroughly considered in the preceding discussion of the systematic position of the genus.

PLATE 1

Figures — Page

1-3. *Margaritaria abrupta* (Conrad) (X 1) 138
Hypotype USNM 644667, Upper Miocene, Yorktown formation, Zone 2 (?), one mile west of Suffolk, Virginia.

4. *Margaritaria inexpectata,* n. sp. (X 1.5) 140
Holotype USNM 644668, Upper Eocene, Jackson Group, Moodys Marl, Creole Bluff, Red River near Montgomery Landing, Louisiana.

5. *Margaritaria gardnerae,* n. sp. (X 1.5) 140
Holotype, USNM 644669, Miocene, Alum Bluff Group, Shoal River Formation, below small waterfall in ravine immediately east of Shell Bluff on Shoal River, Walton County, Florida.

PLATE 1

MARGARITARIA INEXPECTATA Vokes, new species

Pl. 1, fig. 4

Holotype, U.S.N.M. 644668, a fragmentary left valve; length (incomplete) 46 mm; height, (incomplete) 28.9 mm; diameter (single valve, as preserved) 9.8 mm. Upper Eocene, Jackson Group, Moodys Branch Marl, Creole Bluff on Red River near Montgomery Landing, Grant Parish, Louisiana.

Shell elongate-ovate, approximately twice as long as high; anterior margin broadly rounded, posterior subtruncate. Umbones low and inconspicuous, situated near the mid-length of the valve. Surface ornamented by seven radial ribs of which the medial five are relatively strong and equidistant, while the anterior and posterior ones are more weakly developed and inconspicuous. The five medial ribs are most prominent on the umbonal and medial portions of the valve but tend to die out ventrally and are poorly defined at the ventral margins. Interspaces are much wider than the radial ribs. Shell nacreous internally, apparently cellulo-crystalline externally. Hinge edentulous, with rather strong posterior nymph. Adductor scars and pallial line unknown.

The holotype is a fragment representing the dorsal margin and central portion of a left valve that has been preserved mainly as a result of the animal forming a thick blister-pearl on the interior of the valve, the margins of the preserved material corresponding almost exactly with the margins of the pearly thickening. Despite the relative inadequacy of the type material the great extension of the range of the genus revealed by its presence in the upper Eocene faunas makes its formal description desirable.

In all of its general characteristics, this species appears to be similar to *Margaritaria abrupta* Conrad. A comparison of the figures of the two species on Plate 1 suggests that the radial ornamentation is somewhat more strongly developed in the Eocene species than in the Miocene one. This is generally true, insofar as the specimens available for study are concerned, but these reveal a considerable degree of variation in the strength of the ornament and this may even exceed that of the Eocene species if the drawing of *M. abrupta,* shown on plate 95, fig. 5 of the Maryland Geological Survey volume on the Miocene deposits of that state, is reliable in this respect.

There is some suggestion that the number of radial ribs may be greater in the new species than in the Conrad form. It is difficult in view of the amount of variation revealed in the latter, to make any certain statement regarding this factor, however. The specimen of *M. abrupta* here figured (see fig. 1) has four moderately strong radials with traces suggesting two additional anterior ones. The same situation is indicated in the Maryland Miocene illustration mentioned above. The Eocene fragment has five relatively strong radials and traces of two weaker ones can be observed in favorably reflected light.

Comparison of the growth-lines preserved on the broken holotype with these representative of the same stage of development in *M. abrupta* indicated that the Eocene species was somewhat higher in proportion to its height than the Miocene form, with the posterior length relatively shorter than the anterior.

MARGARITARIA GARDNERAE Vokes, new species

Pl. 1, fig. 5

Holotype, U.S.N.M. 644669, a compressed and somewhat incomplete sandstone cast of a specimen with portions of the original shell adhering. Length (slightly incomplete) 50 mm; height 23 mm; diameter, (paired valves, somewhat distorted by compression) 14.5 mm, with the diameter of the right valve being 9 mm. Miocene, Alum Bluff Group, Shoal River Formation from below a small waterfall in a ravine immediately east of the type area of the formation in the NW¼, Sec. 4, T3N, R21W, Walton County, Florida.

Shell elongate-ovate, subtageloid, with the height of the valve approximately two-fifths of the length. Umbones moderately prominent, situated posteriorly about three-fifths of the length from the anterior end. Valve ornamented by radial ribs that are most strongly developed on the umbonal and medial portions of the surface and tend to weaken and become indistinct toward the ventral margin. Eleven radials are present on the holotype (and only known) specimen; the anterior and posterior ones are weak and difficult to discern, the intermediate ones become progressively stronger toward the subumbonal area. Here there are three strong radials with two slightly weaker ones intercalated. Shell slightly granulose at the anterior and posterior ends; growth lines moderately pronounced.

Shell substance internally nacreous, externally cellulo-crystalline. Adductor scars, hinge structures and pallial line unknown.

In contrast to the apparent general similarity of *Margaritaria inexpectata,* n. sp., to *M. abrupta,* the present new species from the Miocene of western Florida is quite different from both the other known forms. Although the type is a compressed and incomplete cast with portions of the shell adhering, it is evident that the species may be distinguished by the fact that the shell is proportionately longer, with slightly more prominent umbones that are more posterior in position than are those of either of the other known species. As may be observed in the accompanying illustrations the umbones of both *M. abrupta* and *M. inexpectata* are almost central in position with respect to the total length of the valves while those of *M. gardnerae* are approximately three-fifths of the total length of the valve from the anterior end. The most obvious difference, however, lies in the greater number of radial ribs, there being eleven such ribs on the present specimen in contrast to the six or seven on the other known species. Furthermore there is a tendency for those radials situated below the umbones to alternate in strength with a weaker one intercalated between the pairs of stronger ribs. No similar development occurs in either *M. abrupta* or *M. inexpectata.*

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August 14, 1964

REVIEWS

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TIME IN STRATIGRAPHY, by Alan B. Shaw. Published by McGraw-Hill Book Company, New York, 1964, xiv + 365 pp., illustrated, $10.50.

This book is a startling reappraisal of paleontology and stratigraphic principles and the use of fossils in stratigraphy. It should be read by every geologist who deals with the correlation of sedimentary rocks. A modern perspective of stratigraphy and its basic principles will be gained by the reader together with new and more refined techniques of time correlation with far greater accuracy than previously possible.

The author first considers the conventional view that all autochthonous and allochthonous marine sediments (not including volcanics) deposited in epeiric seas lie essentially parallel to time planes. He offers evidence to show that these are in fact diachronous. Thus, correlations based simply upon lithologic similarity and continuity are not time correlations and result in erroneous geologic interpretations. He demonstrates that paleogeographic maps based on distribution of lithologies lead to a completely reversed sequence of historical events as interpreted in most studies. The first nine chapters deal with these and other basic elements of stratigraphy and are punctuated with distinct, enumerated, and clearly stated "conclusions." These conclusions are reviewed and synthesized into twelve "principles" in the tenth chapter which concludes the first portion of the book.

In succeeding chapters, Dr. Shaw discusses the relationship of organisms and time, practical geochronologic measure, and methods of correlation by fossils, fossil zones, hemerae, epiboles, index fossils, and range of fossils. The concept of "inadequacy" of the fossil record is discredited convincingly.

In the third section, the author's method of graphic expression of correlation is proposed, considered in relation to disturbances in sedimentary continuity, statistically analysed, and explicitly developed with diagrams and examples. A detailed model study using these graphic techniques is presented in appendices A, B, C, and D. A list of references and an adequate index follow.

In summary, though this book is not an elementary text for stratigraphy, it will be an essential reference for advanced students and research workers in paleontology and stratigraphy.

NATURAL HISTORY, by Richard A. Pimentel. Published by Reinhold Publishing Corporation, New York, 1963, xii + 436 pp., illustrated.

Natural history is the study of a single thing, nature. With this statement, Professor Pimentel begins his book. It is written, as he says, with the firm conviction that field geology, field biology, and ecology can be integrated into a single meaningful study.

Far too few students of biology ever encounter the principles of physical geology or even learn the geologic time scale. In *Natural History,* these fundamentals are put in their proper place as a part of the comprehensible whole of Nature. The universe is described, the Earth is placed in perspective and its layers, seasons, magnetism, and other features are reviewed. The atmosphere, weather and climate, structures and features of the oceans, land forms, glaciation, vulcanism, diastrophism, rock types, and soils are among the geological subjects treated and illustrated with clear diagrams.

Organisms, life processes, classification, nomenclature, and principles of evolution are next considered, followed by conventional systematic exposition of the kingdoms of life and their phyla. The concluding chapters deal with environments, population and community ecology, and ecosystems. A useful glossary and an index are included.

This book represents a creditable effort to present the whole of Natural History. It is well written, well illustrated, and surprisingly comprehensive.

INTRODUCTION TO GEOLOGICAL MICROBIOLOGY, by Sergey Ivanovich Kuznetsov, Mikhail Vladimirovich Ivanov, and Natal'ya Nikolayevna Lyalikova. Translated by Paul T. Broneer, edited by Carl H. Oppenheimer, and published by McGraw-Hill Book Company, New York, 1963, xv + 252 pp., illustrated, $8.95.

Geomicrobiology has been the subject of intensive research in the Soviet Union for many decades. This book, the translation of a pioneer Russian work, reviews the basic principles of microbiology, including the geological environment of microorganisms, distribution, physiology and ecology of bacteria in the lithosphere. This is followed by chapters on the role of microorganisms in the formation, transformation, and destruction of fossil fuel deposits and their effect on economic deposits of sulfur, iron, and related minerals. Short discussions of microbiological prospecting for oil and gas deposits and sulfide ore bodies are included. An extensive list of references and an index are present.

This book summarizes the past work and current efforts of Russian scientists in this area of research. It provides an index to the older Soviet literature and a valuable reference for the economic geologist.

August 14, 1964

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HUBERT C. SKINNER
Editor

TULANE UNIVERSITY OF LOUISIANA
New Orleans

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CONTENTS

VOLUME 3

NUMBER		PAGE
1.	PLEISTOCENE FORAMINIFERA OF THE GULF COAST W. H. Akers and J. H. Dorman	1
	ADDITIONS TO THE NEW WORLD TURBINELLAS Emily H. Vokes	95
2.	GEOLOGY OF THE ABBEVILLE-PERRY-SOUTH PERRY STRUCTURE VERMILION PARISH, LOUISIANA R. O. Steinhoff	97
	REVISION OF THE FORAMINIFERAL FAMILY PSEUDOPARRELLIDAE VOLOSHINOVA Jere H. Lipps	117
3.	TAXONOMIC REVISION OF CERTAIN DISCORBACEA AND ORBITOIDEA (FORAMINIFERIDA) Robert Douglas and William V. Sliter	149
	PHOTOMETRIC DETERMINATION OF PREFERRED ORIENTATION OF FELDSPARS IN FINE-GRAINED IGNEOUS ROCKS Joseph D. Martinez	165
	CENOZOIC VERTEBRATES FROM THE GULF COASTAL PLAIN—I Andrew A. Arata and Crawford G. Jackson, Jr.	175
	REVIEWS: THE FABRIC OF GEOLOGY; THE FOUNDERS OF GEOLOGY; ILLUSTRATIONS OF THE HUTTONIAN THEORY OF THE EARTH Hubert C. Skinner	179
4.	CENOZOIC MURICIDAE OF THE WESTERN ATLANTIC REGION PART II—CHICOREUS *sensu stricto* AND CHICOREUS (SIRATUS) Emily H. Vokes	181
	NOTE ON THE AGE OF THE CHIPOLA FORMATION (MIOCENE) OF NORTHWESTERN FLORIDA Emily H. Vokes	205

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Volume 3, Number 1 December 30, 1964

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W. H. AKERS and J. H. DORMAN
THE CALIFORNIA COMPANY
NEW ORLEANS, LOUISIANA p. 1

ADDITIONS TO THE NEW WORLD TURBINELLAS
EMILY H. VOKES
TULANE UNIVERSITY p. 95

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NEW ORLEANS, LOUISIANA

CONTENTS

Page

I. Abstract 1
II. Introduction 1
A. Geologic Setting 2
B. Acknowledgments 2
III. Foraminifera as Age Determinants 4
A. Review of Methods; Problems in Application to Upper Cenozoic Sediments 4
B. Ranges of Planktonic Foraminifera as Age Determinants; Middle Tertiary to Recent 8
IV. Comparison of Louisiana Pleistocene Assemblages With Other Foraminiferal Faunas of Pleistocene Age 10
V. Paleoecologic Considerations 11
A. Frequency Chart 11
Figure 3: Frequency Chart ..... Folded Insert
VI. Recent Assemblages at the Well Site of the South Pass Block 41 Well 12
VII. Notes on Species and Descriptions of New Taxa 13
A. Planktonic Foraminifera 13
B. Benthonic Foraminifera 20
VIII. Illustrations 59
A. Photography 59
References and Literature Cited 60
Plates I-XV 63-93

I. Abstract

238 species and 21 subspecies of Foraminifera are identified in the Louisiana Pleistocene. Five species and three subspecies are new. Stratigraphic ranges of forms previously thought more restricted are emended. Sedimentary cycles are indicated by foraminiferal frequencies in cores from a well near the edge of the continental shelf. Trans-Atlantic correlation of Gulf Coast sediments is suggested by the discovery in coastal Louisiana wells of Calabrian index fossils.

II. Introduction

The purpose of this report is to record the species, frequencies, and associations of Foraminifera in samples from the Pleistocene of subsurface Louisiana. One hundred

Editorial Committee for this Paper:

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forty-seven cores from the upper 4300 feet of a well drilled at the mouth of the Mississippi River near the edge of the continental shelf constituted the bulk of the material examined during this investigation (figure 1), but additional cores from other wells were also used as indicated in the notes on species.

A. Geologic Setting

Sedimentary cycles are evidenced in the subsurface marine Pleistocene of the Gulf Coast by the vertical distribution of foraminiferal tests and other constituents of the sediments. These cycles have been correlated with the alluvial terrace formations to the north in Louisiana by dense well control (Akers and Holck, 1957). The lowest cycle and the one which contains the greatest marine transgression, the Williana, is considered to represent Nebraskan and Aftonian time. However, there is disagreement on the subdivisions within the Pleistocene and the ages of the terraces, and Doering (1958) considers both the Williana and the overlying Bentley to be of pre-Nebraskan (Calabrian) age.

The Calabrian of the Italian Mediterranean region was formerly considered Pliocene. It was placed in the Pleistocene with the definition by the 18th International Geological Congress of the Plio-Pleistocene boundary as the "time of the first appearance of 'cold' northern species of marine invertebrates, including *Hyalinea balthica* (Schroeter), in the continuous Plio-Pleistocene sequences of Italy." As now defined, the Pleistocene of Europe contains deposits which antedate the Günz glaciations, and we would expect the thick, subsurface Gulf Coast section to contain beds of equivalent age (pre-Nebraskan Pleistocene or Calabrian). Our present study has disclosed evidence for such deposits with the identification of the "cool water immigrants," *Hyalinea balthica* (Schroeter) and *Globigerina inflata* d'Orbigny, near the mouth of the Mississippi river at depths in excess of 4200 feet. The base of the Pleistocene (base of Calabrian) in the South Pass Block 41 well may be at a depth of approximately 10,000 feet. The base of the Nebraskan is thought to be in the vicinity of 4200 feet. (Akers and Holck, 1957).

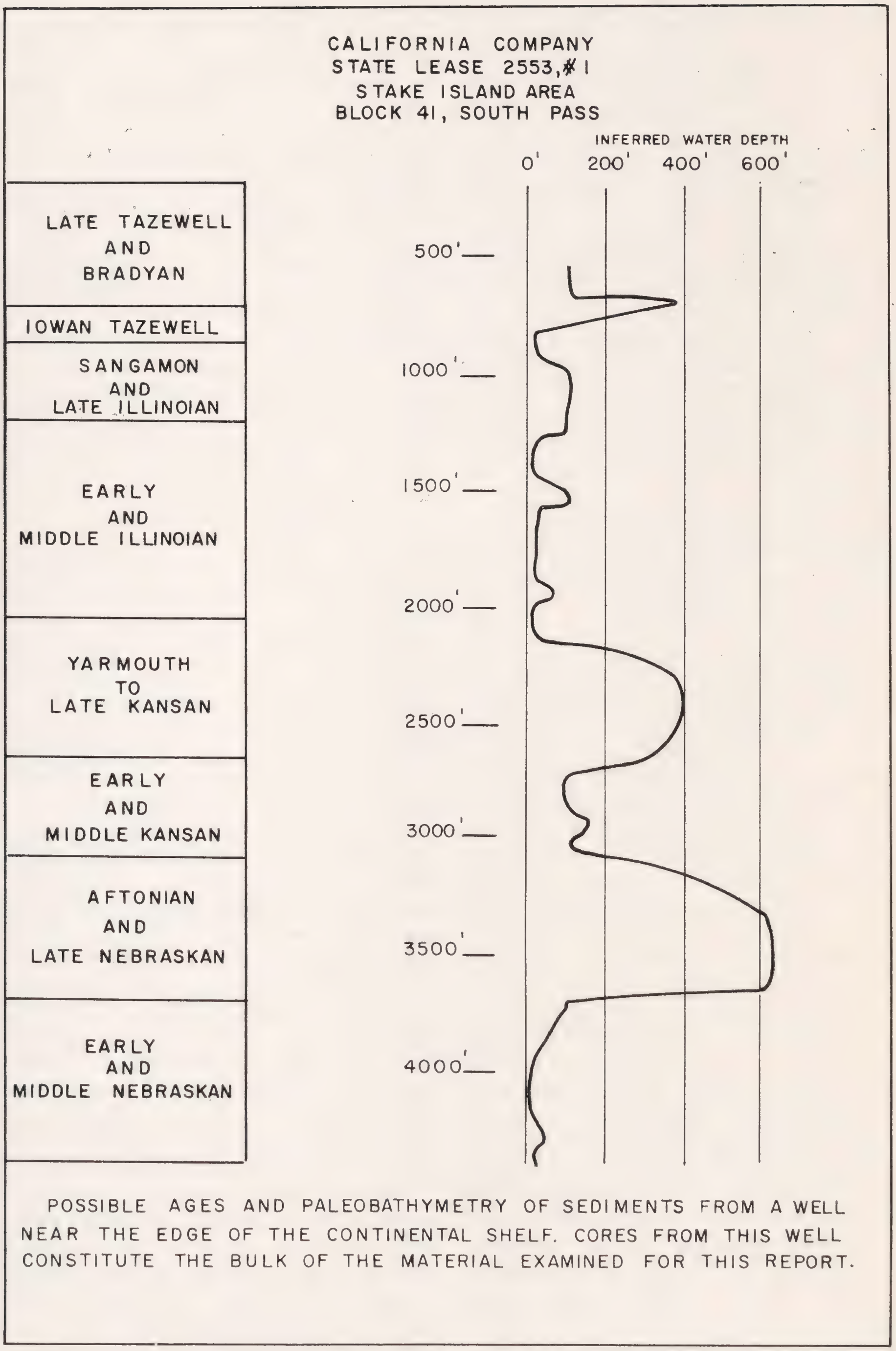
The presence of 10,000 feet of Quaternary sediments at the edge of the continental shelf of Louisiana is not surprising if one recalls that the strand line was farther inland during the long interglacial ages and that not only the present shelf area but some of the inshore areas received sediments and supported a marine environment. As a result of these conditions, "the most nearly complete record of Pleistocene history in this country should be found in the sediments of the Gulf Coastal area and the offshore continental shelf" (Trowbridge, 1954, p. 810).

Ranges of species from the section of possible Calabrian age, (the pre-Nebraskan Pleistocene of Doering, 1958), are not charted in our present study of Pleistocene Foraminifera.

B. Acknowledgments

This project was supported by The California Company. We are grateful to the other members of the Paleontology Staff of The California Company for suggestions and assistance. R. J. Drury and D. K. Cameron were particularly helpful with preparation of material. Alfred R. Loeblich, Jr., and Miss Ruth Todd loaned types from the United States National Museum. Miss Todd also compared types of some of the Recent and Miocene species. Comparisons facilitated by these individuals contributed to the taxonomic study and also to our understanding of foraminiferal ranges. Foraminiferal comparisons and identifications were aided by Recent and Tertiary samples from the Caribbean region, the Mediterranean region, and China. Some of these were made available to the senior writer during the past ten years by H. M. Bolli, Li-Sho Chang, M. B. Cita, B. L. Hill, Jr., H. V. Kaska, A. R. Loeblich, Jr., G. C. Munsey, Jr., C. M. Quigley, Jr., G. Ruggieri, and H. E. Stacy. Mr. E. Robinson of the Geological Survey of Jamaica assisted the senior writer for three days in the field, and it was possible by means of his cooperation to obtain assemblages from the younger Tertiary of Jamaica for comparison with our Pleistocene faunules.

Some phases of the work would have been delayed for years, and other phases could not have been accomplished at all, if previous results of taxonomic, ecologic, and stratigraphic investigations in the Gulf-Caribbean and Mediterranean regions had not been made available. The following significant publications are among these: For the Gulf Coast Foraminifera of Middle Tertiary to



POSSIBLE AGES AND PALEOBATHYMETRY OF SEDIMENTS FROM A WELL NEAR THE EDGE OF THE CONTINENTAL SHELF. CORES FROM THIS WELL CONSTITUTE THE BULK OF THE MATERIAL EXAMINED FOR THIS REPORT.

FIGURE 1

Pleistocene age, Cole (1931), Cushman (1918, 1930), and Cushman and Cahill (1933); for the Tertiary and Pleistocene of the Caribbean region, Bermudez (1949, 1950), Coryell and Rivero (1940), Cushman and Todd (1945), Drooger (1953), Galloway and Heminway (1941), and Renz (1948); for the Tertiary and Pleistocene of the Mediterranean region, Foraminiferi Padani (AGIP Mineraria, 1957), Ascoli (1957), Cita (1957), Colom (1946), Cuvillier and Szakall (1949), Dardenne (1954), d'Orbigny (1846), LeCalvez (1956), and Zei (1956); for Recent Foraminifera, Andersen (1961), Brady (1884), Cushman (1918-1931), d'Orbigny (1839), Parker (1954), Phleger (1955), Phleger and Parker (1951), and Phleger, Parker, and Peirson (1953). Other useful reports are cited within the text and are included in our bibliography.

This paper would not have gone to press without the insistence, encouragement, and editorial guidance of Professor Hubert C. Skinner of Tulane University.

III. Foraminifera as Age Determinants

A. Review of Methods; Problems in Application to Upper Cenozoic Sediments

Paleontologists have attempted to determine the relative ages of fossil assemblages by (1) comparing the percentages of Recent species in the assemblages; (2) comparing the number of species in common with those of other faunas (proportional species correlation); and (3) using the known stratigraphic ranges of the species as a standard. It is a fatuous assumption that Upper Cenozoic beds can be dated exclusively by means of the percentages of species in common with the Recent or by the proportional species correlation method. All three methods may be misleading because of (1) insufficient knowledge of both Recent and fossil faunas; (2) different opinions as to specific identification; and (3) inadequate understanding of the influence of ecologic factors.

All Cenozoic samples in our collection were examined, and a search of the literature was made in order to tabulate other occurrences of the Louisiana Pleistocene Foraminifera (figure 2). Comparisons of our Pleistocene Foraminifera with Tertiary and Recent species were made by means of the literature and by topotype material from Austria, France, Italy, Florida, Jamaica, and the Gulf of Mexico. Primary types of many of the species from the Gulf of Mexico and the Atlantic Ocean were borrowed from the United States National Museum. It should be pointed out that comparison of specimens with only the holotype and a few paratypes may be misleading and can result in synonymy. When possible, adequate topotype material should be examined for an understanding of the ranges of variation shown by any particular form. One of the most important conclusions reached from this study is that far more comprehensive studies of Foraminifera must be made both horizontally and vertically in order to understand the evolution and ecology of these organisms. This idea is in accord with Ager (1956) who holds that "geographical studies on the largest possible scale are essential to the true understanding of any fossil species and are the most likely lines of attack for the accurate unravelling of any fossil lineage." Comprehensive taxonomic studies of worldwide material, like that by Boltovskoy (1958) on *Melonis affine* (Reuss), are essential if we are to develop a more intelligible foraminiferal nomenclature.

Of the 221 forms charted, only 77 have been recorded in the literature on other Pleistocene sediments, 96 from the Pliocene of the world, 82 from the Miocene of the Gulf Coast, 125 from the Miocene of the Caribbean region, and 192 from Recent seas. Many of the Foraminifera herein recorded have previously been reported from Miocene and Recent sediments but not from Pliocene or Pleistocene, although some of the species previously described from deep-sea cores may be of Pleistocene age rather than Recent. This literature gap is largely due to the relative inaccessibility in the Gulf-Caribbean regions of Pliocene and Pleistocene deposits which contain these Foraminifera. Drilling on the continental shelf off Louisiana has disclosed Pleistocene facies favorable for filling the gap in the ranges of some of these Middle Tertiary to Recent species; the ranges of a few species have been extended from the Miocene to the Pleistocene; some species previously unknown, except in Recent sediments, are recorded from the Pleistocene; and a few previously undescribed species appear to be restricted to the Pleistocene.

GULF COAST PLEISTOCENE FORAMINIFERA	TYPE HORIZON AND TYPE LOCALITY	RECENT	OTHER PLEISTOCENE	PLIOCENE	MIOCENE		
					GULF COAST	CARIBBEAN	OTHER
PLANKTONIC							
GLOBIGERINA AEQUILATERALIS H. B. BRADY	RECENT; N. PACIFIC OCEAN	X	X	X	X	X	WORLD-WIDE
GLOBIGERINA ALTISPIRA ALTISPIRA CUSHMAN AND JARVIS	MIOCENE; JAMAICA		?	X	X	X	WORLD-WIDE
GLOBIGERINA BRADYI WIESNER	RECENT; SOUTHERN OCEAN	X			X	X	
GLOBIGERINA BULLOIDES D'ORBIGNY	RECENT; ADRIATIC SEA	X	X	X	X	X	WORLD-WIDE
GLOBIGERINA CONGLOBATA H. B. BRADY	RECENT; ATLANTIC OCEAN	X	X	X	X	X	ITALY
GLOBIGERINA EGGERI RHUMBLER	RECENT; ATLANTIC AND PACIFIC OCEANS	X	X	X			
GLOBIGERINA GLUTINATA EGGER	RECENT; OFF E. COAST OF BRAZIL	X	X	X	X	X	ITALY
GLOBIGERINA INFLATA D'ORBIGNY	RECENT; CANARY ISLANDS	X	X	X			
GLOBIGERINA PARKERAE (LOEBLICH AND TAPPAN)	RECENT; GULF OF MEXICO	X	X	X	X	X	
GLOBIGERINA RUBRA D'ORBIGNY	RECENT; WEST INDIES	X	X	X	X	X	WORLD-WIDE
GLOBIGERINA TRILOBA REUSS	TERTIARY; GERMANY	X	X	X	X	X	WORLD-WIDE
GLOBIGERINA UNIVERSA (D'ORBIGNY)	RECENT; ADRIATIC SEA	X	X	X	X	X	WORLD-WIDE
GLOBOROTALIA HIRSUTA (D'ORBIGNY)	RECENT; CANARY ISLANDS	X	X	X	X	X	ITALY, FIJI
GLOBOROTALIA MENARDII MENARDII (D'ORBIGNY)	RECENT; ADRIATIC SEA	X	X	X	X	X	WORLD-WIDE
GLOBOROTALIA MENARDII MIOCENICA D. K. PALMER	MIOCENE; JAMAICA		?	X	X	X	MOROCCO
GLOBOROTALIA MENARDII MULTICAMERATA CUSHMAN AND JARVIS	MIOCENE; JAMAICA		?	?	X	X	
GLOBOROTALIA MENARDII TUMIDA (H. B. BRADY)	RECENT?; BEACH, NEW GUIANA	X	X	X			TAIWAN
GLOBOROTALIA PUNCTULATA (D'ORBIGNY)	RECENT?; RIMINI, ITALY	X	X	X	X	X	ITALY, TAIWAN
GLOBOROTALIA TRUNCATULINOIDES (D'ORBIGNY)	RECENT; CANARY ISLANDS	X	X	X			
PULLENIATINA OBLIQUILOCULATA (PARKER AND JONES)	RECENT; ATLANTIC AND INDIAN OCEANS	X	X	X	?	X	
SPHAEROIDINELLA DEHISCENS (PARKER AND JONES)	RECENT; ATLANTIC OCEAN	X	X	X	X	X	
BENTHONIC							
AMPHISTEGINA LESSONII D'ORBIGNY	RECENT; L'ILE-DE-FRANCE	X	X	X	X	X	WORLD-WIDE
ARCHAIAS ANGULATUS (FICHTEL AND MOLL)	RECENT; MEDITERRANEAN (?), ARABIAN SEA	X	X	X	X	X	
ARTICULINA AURICULATA (EGGER)	RECENT; INDIAN OCEAN	X					
ARTICULINA MAYORI CUSHMAN	RECENT; DRY TORTUGAS ISLANDS	X			X		
ARTICULINA PAUCICOSTATA CUSHMAN	RECENT; OFF DRY TORTUGAS, FLA.	X					
ASTERIGERINA CARINATA D'ORBIGNY	RECENT; CUBA AND JAMAICA	X	X		X	X	
BIGENERINA IRREGULARIS PHLEGER AND PARKER	RECENT; GULF OF MEXICO	X					
BIGENERINA TEXTULARIOIDEA (GOËS)	RECENT; PROBABLY CARIBBEAN	X	X	X	X	X	MALLORCA
BILOCULINELLA TODDAE ANDERSON							
BOLIVINA ACEROSA CUSHMAN	MIOCENE; DOMINICAN REPUBLIC		?	X		X	
BOLIVINA ALATA (SEGUENZA)	PLEISTOCENE; ITALY	X	X	X	X	X	ITALY, MALLORCA
BOLIVINA ALBATROSSI CUSHMAN	RECENT; ATLANTIC OCEAN	X				X	
BOLIVINA BARBATA PHLEGER AND PARKER	RECENT; GULF OF MEXICO	X					
BOLIVINA CATANENSIS SEGUENZA	PLEISTOCENE; SICILY	X	X	X			MALLORCA
BOLIVINA DAGGARIUS PARKER	RECENT; GULF OF MEXICO	X					
BOLIVINA DIFFORMIS (WILLIAMSON)	RECENT; PROBABLY BRITISH ISLES	X	X				
BOLIVINA FRAGILIS PHLEGER AND PARKER	RECENT; GULF OF MEXICO	X					
BOLIVINA GOESII CUSHMAN	RECENT; ATLANTIC OCEAN	X					
BOLIVINA HASTATA PHLEGER AND PARKER	RECENT; GULF OF MEXICO	X					
BOLIVINA LOWMANI PHLEGER AND PARKER	RECENT; GULF OF MEXICO	X					
BOLIVINA MINIMA PHLEGER AND PARKER	RECENT; GULF OF MEXICO	X					
BOLIVINA ORDINARIA PHLEGER AND PARKER	RECENT; GULF OF MEXICO	X					
BOLIVINA PACIFICA CUSHMAN AND MC CULLOCH	RECENT; PACIFIC OCEAN	X					
BOLIVINA PLICATELLA CUSHMAN	RECENT; ATLANTIC OCEAN	X	X	X	X	X	
BOLIVINA SPINATA CUSHMAN	RECENT; CARIBBEAN	X					
BOLIVINA SUBAENARIENSIS CUSHMAN	RECENT; ATLANTIC OCEAN	X	?				
BOLIVINA SUBAENARIENSIS LUCIDA AKERS AND DORMAN	PLEISTOCENE; LA. GULF COAST	X	?			?	
BOLIVINA SUBAENARIENSIS MEXICANA CUSHMAN	RECENT; GULF OF MEXICO	X		X		X	
BOLIVINA SUBSPINESCENS CUSHMAN	RECENT; ATLANTIC OCEAN	X					EGYPT
BOLIVINA THALMANNI RENZ	MIOCENE; VENEZUELA				X	X	
BOLIVINA TRANSLUCENS PHLEGER AND PARKER	RECENT; GULF OF MEXICO	X					
BUCCELLA HANNAI PHLEGER AND PARKER	RECENT; GULF OF MEXICO	X					
BULIMINA ACULEATA D'ORBIGNY	RECENT; ITALY	X		X		X	ITALY, MOROCCO, MALLORCA
BULIMINA ALAZANENSIS SPATIOSA CUSHMAN AND TODD	MIOCENE; JAMAICA					X	
BULIMINA MARGINATA D'ORBIGNY	RECENT; RIMINI, ITALY	X	X	X	X	X	ITALY
BULIMINA PATAGONICA D'ORBIGNY	RECENT; BAY OF SAN-BLAS, ARGENTINA	X					
BULIMINA SPICATA PHLEGER AND PARKER	RECENT; GULF OF MEXICO	X					
BULIMINA STRIATA MEXICANA CUSHMAN	RECENT; ATLANTIC OCEAN	X				X	
BULIMINELLA ELEGANTISSIMA D'ORBIGNY	RECENT; W. COAST OF S. AMERICA	X	X	X	X	X	OFF W. COAST OF S. AMERICA
CANCRIS SAGRA (D'ORBIGNY)	RECENT; CUBA AND JAMAICA	X	X	X	X	X	
CASSIDULINA CARINATA SILVESTRI	PLIOCENE; ITALY	X	X	X	X		ITALY
CASSIDULINA CRASSA D'ORBIGNY	RECENT; FALKLAND ISLANDS	X	X	X	X	X	ITALY, AUSTRIA
CASSIDULINA CURVATA PHLEGER AND PARKER	RECENT; GULF OF MEXICO	X					
CASSIDULINA LAEVIGATA D'ORBIGNY	NOT GIVEN	X	X	X	X	X	CALIFORNIA, ITALY
CASSIDULINA NORCROSSI AUSTRALIS PHLEGER AND PARKER	RECENT; GULF OF MEXICO	X					
CASSIDULINA SUBGLOBOSA H. B. BRADY	RECENT; NOT GIVEN	X	X	X	X	X	ITALY, MOROCCO
CIBICIDES IO CUSHMAN	RECENT; W. COAST OF PATAGONIA	X		X	X	X	
CIBICIDES NUCLEATUS (SEGUENZA)	MIOCENE; ITALY	X			X	X	ITALY, BALEARIC ISLANDS
CIBICIDES UMBONATUS PHLEGER AND PARKER	RECENT; GULF OF MEXICO	X					
CLAVULINA MEXICANA CUSHMAN	RECENT; GULF OF MEXICO	X				X	CALIFORNIA, FRANCE
CUNEOLINA ANGUSTA CUSHMAN	MIOCENE; JAMAICA	X				X	
CYCLAMMINA CANCELLATA H. B. BRADY	RECENT; NOT GIVEN	X		X	X	X	WORLD-WIDE
CYCLOGYRA PLANORBIS (SCHULTZE)	RECENT; COAST OF MOZAMBIQUE	X					

FIGURE 2—Geographic and Stratigraphic Occurrence of Louisiana Pleistocene Foraminifera

GULF COAST PLEISTOCENE FORAMINIFERA	TYPE HORIZON AND TYPE LOCALITY	RECENT	OTHER PLEISTOCENE	PLIOCENE	MIOCENE		
					GULF COAST	CARIBBEAN	OTHER
DENTALINA VERTEBRALIS ALBATROSSI (CUSHMAN)	RECENT; GULF OF MEXICO	X				X	MALLORCA
DENTALINA COMMUNIS D'ORBIGNY	RECENT; ADRIATIC SEA	X	X	X	X	X	MALLORCA, MORROCCO
ELPHIDIUM DISCOIDALE (D'ORBIGNY)	RECENT; CUBA AND JAMAICA	X	?	?		X	
ELPHIDIUM FIMBRIATULUM (CUSHMAN)	PLIOCENE; FLORIDA	X	X	X	X	X	
ELPHIDIUM POEYANUM (D'ORBIGNY)	RECENT; CUBA AND JAMAICA	X	X	X	X	X	
ELPHIDIUM SAGRUM (D'ORBIGNY)	RECENT; CUBA	X	X	X	X	X	
EPISTOMINELLA VITREA PARKER	RECENT; GULF OF MEXICO	X		X			
EPONIDELLA GARDENISLANDENSIS AKERS	RECENT; GULF OF MEXICO	X					
FRONDICULARIA SAGITTULA VANDEN BROECK	RECENT; WEST INDIES	X				X	
FURSENKOINA COMPLANATA (EGGER)	RECENT; OFF WESTERN AUSTRAILIA	X	X	X		X	
FURSENKOINA FINISSIMA AKERS AND DORMAN	PLEISTOCENE; LA. GULF COAST						
FURSENKOINA MEXICANA (CUSHMAN)	RECENT; GULF OF MEXICO	X					
FURSENKOINA PONTONI (CUSHMAN)	MIOCENE; FLORIDA	X			X	X	CALIFORNIA
FURSENKOINA SCHREIBERSIANA (CZJZEK)	MIOCENE; VIENNA BASIN	X	X	X	?	?	CALIFORNIA; ITALY
GAUDRYINA AEQUA CUSHMAN	RECENT; ATLANTIC OCEAN	X					
GAUDRYINA (PSEUDOGAUDRYINA) ATLANTICA (BAILEY)	RECENT; ATLANTIC OCEAN	X	?		X	X	
GLOBOBULIMINA AFFINIS (D'ORBIGNY)	RECENT; CUBA	X	X	X		X	ITALY, MALLORCA
GLOBOBULIMINA MISSISSIPPIENSIS PARKER	RECENT; GULF OF MEXICO	X					
GLOBULINA CARIBAEA D'ORBIGNY	RECENT; CUBA	X					
GUTTULINA AUSTRALIS (D'ORBIGNY)	RECENT; BAY OF SAN-BLAS, ARGENTINA	X					MARYLAND, S. CAROLINA
GUTTULINA PULCHELLA D'ORBIGNY	RECENT; CUBA AND MARTINIQUE	X		X			
GYPSINA VESICULARIS (PARKER AND JONES)	PROBABLY RECENT; NOT GIVEN	X			X	X	
GYROIDINA NEOSOLDANII BROTZEN	RECENT; S. PACIFIC, N. PACIFIC	X	X	X			ITALY
GYROIDINA ORBICULARIS D'ORBIGNY	RECENT; ADRIATIC SEA, NEAR RIMINI	X					VIRGINIA
GYROIDINOIDES REGULARIS (PHLEGER AND PARKER)	RECENT; GULF OF MEXICO	X					
GYROIDINOIDES SOLDANII ALTIFORMIS (R. E. AND K. C. STEWART)	PLIOCENE; CALIFORNIA	X		X	X	X	ITALY
HANZAWAIA CONCENTRICA (CUSHMAN)	MIOCENE; FLORIDA	X	X	X	X	X	
HANZAWAIA STRATTONI (APPLIN)	MIOCENE; LOUISIANA	X			X	?	
HAUERINA NACCHARA AKERS AND DORMAN	PLEISTOCENE; LA. GULF COAST						
HÖGLUNDINA ELEGANS (D'ORBIGNY)	NOT GIVEN; PLIOCENE, ITALY?	X	X	X		X	MEDITERRANEAN REGION
HYALINEA BALTHICA (SCHROETER)	RECENT; BALTIC SEA	X	X				
KARRERIELLA BRADYI (CUSHMAN)	RECENT; ATLANTIC OCEAN	X	X	X	X	X	BALEARIC ISLANDS, ITALY
KARRERIELLA CYCLOSTOMATA SINUATA AKERS AND DORMAN	PLEISTOCENE; LA. GULF COAST						
LAGENA GRACILLIMA (SEGUENZA)	MIOCENE; SICILY	X		X			SICILY, ITALY
LAGENA GRACILLIMA MOLLIS CUSHMAN	RECENT; CASCO BAY, MAINE	X					
LAGENA HEXAGONA (WILLIAMSON)	RECENT; ENGLAND	X	X	X	X	X	ITALY
LAGENA STRIATA (D'ORBIGNY)	RECENT; FALKLAND ISLANDS	X	X	X	X	X	MEDITERRANEAN REGION
LAGENA SULCATA SPICATA CUSHMAN AND MC CULLOCH	RECENT; PACIFIC OCEAN	X					
LENTICULINA BOWDENENSIS (CUSHMAN)	MIOCENE; JAMAICA	X				X	
LENTICULINA CALCAR (LINNÉ)	RECENT; ADRIATIC SEA	X	X	X	X	X	WORLD-WIDE
LENTICULINA CULTRATUS (MONTFORT)	PLIOCENE; ITALY	X	X	X	X	X	MEDITERRANEAN REGION
LENTICULINA LUCIDUS (CUSHMAN)	RECENT; ATLANTIC OCEAN	X				X	
LENTICULINA MELVILLI (CUSHMAN AND RENZ)	MIOCENE; VENEZUELA					X	
LENTICULINA OCCIDENTALIS (CUSHMAN)	RECENT; N. ATLANTIC OCEAN	X					
LENTICULINA ORBICULARIS (D'ORBIGNY)	TERTIARY; ITALY	X	X	X	X	X	ITALY, MOROCCO
LENTICULINA PEREGRINA (SCHWAGER)	MIOCENE; KAR NIKOBAR	X		X		X	JAPAN, ITALY
LENTICULINA ROTULATUS (LAMARCK)	TERTIARY; FRANCE	X	X	X	X	X	ITALY; MOROCCO
LENTICULINA SENNI LACRIMATUS AKERS AND DORMAN	PLEISTOCENE; LA. GULF COAST						
LIEBUSELLA SOLDANII (JONES AND PARKER)	MIOCENE; SANTA DOMINGO	X				X	FRANCE
MARGINULINA BASISPINOSA CUSHMAN AND RENZ	MIOCENE; VENEZUELA					X	
MARGINULINA GLABRA D'ORBIGNY	PLIOCENE; SIENNA, ITALY	X	X	X	X	?	ITALY, MOROCCO
MARGINULINA MARGINULINOIDES (GOËS)	RECENT; GULF OF MEXICO	X					
MARGINULINA SUBACULEATA GLABRATA (CUSHMAN)	RECENT; GULF OF MEXICO	X				X	
MARGINULINA SUBLITUUS MULTICAMERATA CUSHMAN AND STAINFORTH	MIOCENE; TRINIDAD					X	
MELONIS AFFINE (REUSS)	OLIGOCENE; GERMANY	X	X	X	X	X	WORLD-WIDE
NEOEPONIDES CORYELLI (PALMER)	MIOCENE; JAMAICA					X	
NEOEPONIDES PARANTILLARUM (GALLOWAY AND HEMINWAY)	MIOCENE; PUERTO RICO		X			X	
NEOEPONIDES TUMIDULUS (H. B. BRADY)	RECENT; S. ATLANTIC OCEAN	X					
NEOEPONIDES TURGIDUS (PHLEGER AND PARKER)	RECENT; GULF OF MEXICO	X					
NODOBACULARIELLA ATLANTICA CUSHMAN AND HANZAWA	RECENT; ATLANTIC OCEAN	X					
NODOBACULARIELLA CASSIS (D'ORBIGNY)	RECENT; SHORE SANDS, CUBA	X		X	X	X	
NODOSARIA COMATULA CUSHMAN	RECENT; GULF OF MEXICO	X			X	X	
NODOSARIA FUSTA CUSHMAN AND TODD	MIOCENE; JAMAICA					X	
NODOSARIA HISPIDA D'ORBIGNY	TERTIARY; AUSTRIA	X	X	X	X	X	MOROCCO, FRANCE
NODOSARIA PYRULA D'ORBIGNY	PLIOCENE; SIENNA, ITALY	X		X		X	CALIFORNIA
NODOSARELLA GRACILLIMA (CUSHMAN AND JARVIS)	MIOCENE; TRINIDAD					X	
NONION GRATELOUPI (D'ORBIGNY)	RECENT; CUBA	X	X	X	X	X	FRANCE
NONIONELLA ATLANTICA CUSHMAN	RECENT; ATLANTIC OCEAN	X	X			X	
NONIONELLA OPIMA CUSHMAN	RECENT; ATLANTIC OCEAN	X					
ORIDORSALIS UMBONATUS ECUADORENSIS (GALLOWAY AND MORREY)	EOCENE?; ECUADOR	X		X	X	X	ITALY
PAVONINA ATLANTICA CUSHMAN	RECENT; ATLANTIC OCEAN	X			X	X	
PENEROPLIS PROTEUS D'ORBIGNY	RECENT; CUBA AND JAMAICA	X	X	X	X	X	
PLANORBULINA MEDITERRANENSIS D'ORBIGNY	RECENT; MEDITERRANEAN COAST	X	X	X	X	X	ITALY, MALLORCA, AUSTRIA
PLANULARIA QUASITRINAE AKERS AND DORMAN	PLEISTOCENE; LA. GULF COAST						
PLANULINA EXORNA PHLEGER AND PARKER	RECENT; GULF OF MEXICO	X					
PLANULINA FOVEOLATA (H. B. BRADY)	RECENT; BERMUDA	X				X	
PLANULINA WUELLERSTORFI (SCHWAGER)	MIOCENE; KAR NIKOBAR	X	X	X	X	X	KAR NIKOBAR, ITALY, MOROCCO
PLECTOFRONDICULARIA FLORIDANA CUSHMAN	MIOCENE; FLORIDA				X	X	
POROEPONIDES CRIBROREPANDUS ASANO AND UCHIO	PLIOCENE; JAPAN	X		X	X	X	JAPAN
PULLENIA BULLOIDES (D'ORBIGNY)	MIOCENE; AUSTRIA	X	X	X	X	X	ITALY, AUSTRIA, CALIFORNIA
PULLENIA QUINQUELOBA (REUSS)	OLIGOCENE; GERMANY	X	X	X		X	ITALY, MALLORCA, MOROCCO

FIGURE 2 (continued)

GULF COAST PLEISTOCENE FORAMINIFERA	TYPE HORIZON AND TYPE LOCALITY	RECENT	OTHER PLEISTOCENE	PLIOCENE	MIOCENE		
					GULF COAST	CARIBBEAN	OTHER
PYRGO CARINATA (D'ORBIGNY)	RECENT; CUBA AND SAINT THOMAS	X					
PYRGO COMATA (H. B. BRADY)	RECENT; WEST INDIES	X				X	
PYRGO MURRHINA (SCHWAGER)	MIOCENE; KAR NIKOBAR	X				X	KAR NIKOBAR
PYRGO NASUTUS CUSHMAN	RECENT; WEST INDIES	X					
PYRGO VESPERTILIO (SCHLUMBERGER)	RECENT; BAY OF GASCONY	X					
QUINQUELOCULINA AGGLUTINANS D'ORBIGNY	RECENT; JAMAICA	X	X	X			
QUINQUELOCULINA BICOSTATA D'ORBIGNY	RECENT; CUBA	X			X		
QUINQUELOCULINA HORRIDA CUSHMAN	RECENT; OFF S. CAROLINA	X					
QUINQUELOCULINA LAMARCKIANA D'ORBIGNY	RECENT; CUBA AND JAMAICA	X	X	X	X	X	FRANCE
QUINQUELOCULINA POLYGONA D'ORBIGNY	RECENT; CUBA AND JAMAICA	X				X	
RAMULINA GLOBULIFERA H. B. BRADY	RECENT; N. ATLANTIC AND S. PACIFIC	X	X	X		X	SPAIN, ITALY, MALLORCA
RECTOBOLIVINA ADVENA (CUSHMAN)	RECENT; TORTUGAS	X				X	S. CAROLINA (?)
REUSSELLA MINUTA DROOGER AND KAASSCHIETER	RECENT; CARIBBEAN	X					
REUSSELLA MIOCENICA CUSHMAN	MIOCENE; FLORIDA	X			X	X	
ROSALINA BULBOSA (PARKER)	RECENT; NORTHEASTERN GULF OF MEXICO	X					
ROSALINA CONCINNA (H. B. BRADY)	RECENT; PACIFIC OCEAN	X					
ROSALINA FLORIDANA (CUSHMAN)	RECENT; FLORIDA	X	X	X	X	X	
ROSALINA FLORIDENSIS (CUSHMAN)	RECENT; S. OF CAPE HATTERAS	X	X			X	
"ROTALIA" TRANSLUCENS PHLEGER AND PARKER	RECENT; GULF OF MEXICO	X					
SAGRINA PULCHELLA D'ORBIGNY	RECENT; CARIBBEAN SEA	X		X	X	X	AUSTRIA
SARACENARIA ITALICA DEFRANCE	FOSSIL; ITALY	X	X	X	X	X	ITALY, FRANCE
SIGMOILINA DISTORTA PHLEGER AND PARKER	RECENT; GULF OF MEXICO	X			?	?	
SIGMOILOPSIS SCHLUMBERGERI (SILVESTRI)	RECENT; FRANCE	X	X	X		X	ITALY
SIGMOILOPSIS SUBPOEYANA (CUSHMAN)	RECENT; DRY TORTUGAS ISLANDS	X			X	X	
SIPHOGENERINA RAPHANUS (PARKER AND JONES)	RECENT; NOT DESIGNATED	X		X		X	
SIPHONINA PULCHRA CUSHMAN	MIOCENE; CUBA	X		X		X	
SIPHONODOSARIA ANTILLEA (CUSHMAN)	RECENT; ATLANTIC OCEAN	X				?	
SIPHONODOSARIA VERNEUILI (D'ORBIGNY)	MIOCENE; AUSTRIA					X	AUSTRIA, ITALY, SUMATRA
SIPHOTEXTULARIA AFFINIS (FORNASINI)	PLIOCENE; ITALY	X		X			MALLORCA
SIPHOTEXTULARIA ROLSHAUSENI PHLEGER AND PARKER	RECENT; GULF OF MEXICO	X					
SORITES MARGINALIS (LAMARCK)	RECENT; EUROPE	X	X	X	?	X	
SPHAEROIDINA BULLOIDES D'ORBIGNY	RECENT AND FOSSIL; NOT GIVEN	X	X	X	X	X	WORLD-WIDE
SPIRILLINA VIVIPARA EHRENBERG	RECENT; GULF OF MEXICO	X			?	X	
SPIROLOCULINA DEPRESSA D'ORBIGNY	PLIOCENE AND RECENT; ITALY	X	X	X	?	?	ITALY
STETSONIA MINUTA PARKER	RECENT; GULF OF MEXICO	X					
TEXTULARIA CANDEIANA D'ORBIGNY	RECENT; CUBA, MARTINIQUE, SAINT THOMAS	X		X	X	X	
TEXTULARIA CONICA D'ORBIGNY	RECENT; CUBA AND JAMAICA	X	X	X	X	?	
TEXTULARIA FOLIACEA OCCIDENTALIS CUSHMAN	RECENT; CUBA	X			X	X	
TEXTULARIA MAYORI CUSHMAN	RECENT; DRY TORTUGAS ISLANDS	X		X	X		
TEXTULARIA MEXICANA CUSHMAN	RECENT; CARIBBEAN SEA	X		X	X	X	CALIFORNIA, FRANCE
TEXTULARIA SICA LALICKER AND BERMUDEZ	RECENT; CUBA	X					
TEXTULARIELLA BARRETTII (JONES AND PARKER)	RECENT; JAMAICA	X		X	X	X	
TRIFARINA BELLA (PHLEGER AND PARKER)	RECENT; GULF OF MEXICO	X					
TRIFARINA EXIMIA (CUSHMAN AND JARVIS)	MIOCENE; JAMAICA					X	
TRIFARINA HOLCKI AKERS AND DORMAN	PLEISTOCENE; LA. GULF COAST						
TRILOCULINA CIRCULARIS BORNEMANN	OLIGOCENE; GERMANY	X	X	X		X	FRANCE
TRILOCULINA INSIGNIS (H. B. BRADY)	RECENT; CULEBRA ISLAND	X					
TRILOCULINA TRICARINATA D'ORBIGNY	RECENT; RED SEA	X	X	X		X	FRANCE
TRILOCULINA TRIGONULA (LAMARCK)	EOCENE; PARIS BASIN	X	X	X	X	X	
TRIMOSINA DENTICULATA AKERS AND DORMAN	PLEISTOCENE; LA. GULF COAST			X			
TRITAXILINA YASICAENSIS BERMUDEZ	MIOCENE; DOMINICAN REPUBLIC					X	
UVIGERINA BELLULA BANDY	RECENT; GULF OF MEXICO	X					
UVIGERINA FLINTII CUSHMAN	RECENT; FLORIDA STRAIT	X				X	ITALY
UVIGERINA PEREGRINA CUSHMAN	RECENT; ATLANTIC OCEAN	X	X	X	X	X	ITALY
UVIGERINA PEREGRINA BRADYANA CUSHMAN	RECENT; ATLANTIC OCEAN	X		X			CALIFORNIA
UVIGERINA PEREGRINA PARVULA CUSHMAN	RECENT; GULF OF MEXICO	X	X	X		X	
VAGINULINOPSIS PLANATA (PHLEGER AND PARKER)	RECENT; GULF OF MEXICO	X					
VALVULINERIA HERRICKI HADLEY	OLIGOCENE; CUBA					X	
VALVULINERIA LAEVIGATA PHLEGER AND PARKER	RECENT; GULF OF MEXICO	X					
VALVULINERIA MINUTA PARKER	RECENT; GULF OF MEXICO	X					
VALVULINERIA PALMERAE CUSHMAN AND TODD	MIOCENE; JAMAICA	X			X	X	

FIGURE 2 (continued)

Gulf Coast Pleistocene microfaunas show a higher percentage of species in common with microfaunas recorded from the Caribbean Oligo-Miocene than with those recorded from the Miocene of the American Gulf Coast. This could be due partly to a closer similarity of Caribbean Middle Tertiary environmental conditions under which portions of our Pleistocene section were deposited, but it is also due at least in part to a deficiency in the literature on micropaleontology of Gulf Coast subsurface Tertiary deposits. Similarly, the closer statistical relationship with Recent faunas than with other Pleistocene or Pliocene assemblages is a reflection of the more abundant literature on Recent Foraminifera and the relative dearth of information on Upper Tertiary micropaleontology.

Use of the proportional species correlation method is difficult because of differences of opinion concerning limits of variability of a species. It was found that a species may be reported from beds of one age, whereas only a variant of this species may be recorded from beds of another age, for example, *Elphidium fimbriatulum* (Cushman) which is identified in Pliocene and

Miocene sediments, and *E.* cf. *E. fimbriatulum* which is reported from the Gulf of Mexico (Phleger and Parker, 1951, p. 10). *E. poeyanum* (d'Orbigny) has been identified from the Recent and from the Miocene of the Caribbean but not from the Miocene of the Gulf Coast, except as *E.* aff. *E. poeyanum* (Applin and Jordan, 1945, p. 129). *E. discoidale* (d'Orbigny) has been identified in Recent seas and from the Miocene of the Dominican Republic but as *E. discoidale multiloculum* Cushman and Ellisor in the Middle Tertiary of the Gulf Coast (Cushman and Ellisor, 1945, p. 561). *Lagena sulcata* (Walker and Jacob) is reported from both the Atlantic and the Pacific and also from the Middle Tertiary of Texas, Florida, and the Dominican Republic. *L. sulcata spicata* Cushman and McCulloch is reported from various Pacific localities and may also occur in Tertiary sediments having been lumped by investigators with *L. sulcata.*

Specialists in taxonomic work have been inclined to underestimate both the ranges in time and the lateral distribution of foraminiferal species. The result is a battery of synonyms which may be long undiscovered because of the difficulty of comparing holotypes. *Pavonina atlantica* Cushman appears in reports on Foraminifera from the Atlantic and the Gulf of Mexico. *Pavonina miocenica* Cushman and Ponton occurs in reports on the Miocene of Florida, Colombia, the Dominican Republic, and Jamaica. Topotypes and primary types of these species show no basis for differentiation. *Plectofrondicularia floridana* Cushman has been recorded from the Miocene of Florida, Bowden, Jamaica, the Dominican Republic, Colombia, Venezuela, Trinidad, and Barbados. *P. diversicostata* (Neugeboren), another Miocene species, is reported from Buff Bay, Jamaica, and the Miocene of Hungary and Egypt. These are probably conspecific. *Gyroidinoides scalata* (Garrett) from the Gulf Coast Middle Tertiary, *G. planulata* (Cushman and Renz) from the Middle Tertiary of Venezuela, Trinidad, Ecuador, Barbados, and the Dominican Republic, and *G. laevis* (Coryell and Rivero) from the Middle Tertiary of Haiti are obviously related. The latter two species possibly should be considered as synonyms or at least as variants of *G. scalata* (Garrett). *G. regularis* (Phleger and Parker) of Gulf Coast Recent and Pleistocene sediments appears to be descended from *G. scalata* and also may be considered as a variant of that species.

Too frequently, published comparisons of faunas have been made only with other local assemblages or by means of illustrations rather than with actual specimens. Generalizations arrived at by such methods are confusing and misleading, especially for those unfamiliar with the pitfalls of identification and inadequacies of the literature. In charting the type localities and Tertiary records of our Pleistocene Foraminifera, those species and subspecies which were identified with question are omitted. It is necessary to keep in mind the possibility of error in age assignment for the Tertiary rocks from which many of the Foraminifera were described or reported. In most cases the age assignments of the original authors were used, but where recent data have indicated a different age, current concepts have been followed with references, or we have used a more inclusive stratigraphic term. "Middle Tertiary", for example, is employed for those rocks for which Upper Oligocene to Middle Miocene ages have been argued. The Tertiary beds of Kar Nicobar, from which Schwager (1866) described new foraminiferal species, is now considered to be of Miocene age rather than Pliocene, according to Dr. Mohsen-ul Haque, Deputy Director, Geological Survey of Pakistan (personal communication, April 12, 1958).

B. Ranges of Planktonic Foraminifera as Age Determinants—Middle Tertiary to Recent

Most specialists on Foraminiferida have ceased within the last 15 years to apply seriously the gross statistical methods enumerated above to fine age determinations or to regional and inter-regional correlation problems. Recent emphasis has been on planktonic Foraminifera. The Caribbean paleontologists and stratigraphers have made notable contributions in determining and publishing the ranges of this group of fossils in Middle Tertiary and older sediments. The ranges of planktonic species seem to exist in the same relationship to each other wherever they are found, whether in Trinidad, Venezuela, Ecuador, the Louisiana Gulf Coast, Saipan, Sumatra, or the Mediterranean region. Thus a *Globorotalia kugleri-Globigerinatella insueta-Globorotalia fohsi fohsi*

sequence in the Cipero of Trinidad is now generally accepted as synchronous with the same sequence in the Middle Tertiary of any other region. There has long been a need for such definitive work on the Upper Tertiary and Quaternary planktonics. We have supposed that the Pleistocene saw the extinction of some of the Tertiary forms and the incipience of many modern species. A dearth of literature on Pleistocene planktonic species and the relative inaccessibility of sediments of this age containing abundant and well developed planktonics jointly explain the scarcity of information in this field. It is believed that this report helps to fill the gap in the recorded ranges of some of the planktonic species and also of many benthonic forms.

A total of 22 species and subspecies of planktonic Foraminifera are identified in the Louisiana Pleistocene. Nineteen of these were described from the Recent and 3 from the Miocene. Three have not been recorded from Recent sediments, but this report extends the published ranges of these 3 from Tertiary to Lower Quaternary. Seventeen of the species and subspecies are recorded from the Miocene of the American Gulf Coast and 17 from the Oligo-Miocene of the Caribbean region. Only 4 of the Pleistocene forms are not reported from either Gulf Coast Miocene or the Caribbean Oligo-Miocene.

Globigerina altispira altispira Cushman and Jarvis, *Globorotalia menardii miocenica* D. K. Palmer, and *G. menardii multicamerata* Cushman and Jarvis were described from the Miocene of Jamaica and have not been recorded as occurring above the Pleistocene. These three foraminifers have not been established previously in sediments younger than Miocene. In coastal and offshore Louisiana, however, *Globorotalia menardii miocenica* is a guide fossil for the Lower Pleistocene. The subsurface interval which contains this useful foraminifer has been identified in wells from the mouth of the Mississippi River to continental shelf areas off eastern Texas. Specimens of *Globigerina eggeri* Rhumbler from modern deep sea samples closely resemble *G. altispira altispira* in having apertural teeth; and occasionally specimens of *Globorotalia menardii menardii* (d'Orbigny) are found in Recent assemblages which are closely related to *G. menardii multicamerata.*

The three planktonic species which have not been recorded from sediments as old as Miocene are *Globigerina eggeri* Rhumbler, *G. inflata* d'Orbigny, and *G. truncatulinoides* (d'Orbigny). We have seen all of these in the Louisiana Pliocene, but not in older beds. *Globorotalia truncatulinoides* and *Globigerina inflata* have been reported from the Italian Pliocene, although Colom (1954, p. 49) has been unable to verify the latter species in pre-Pleistocene sediments of the Mediterranean region.

The general aspect of early Pleistocene planktonic assemblages is closer to that of Recent assemblages than to Miocene. Although most of the planktonic species and subspecies of the Pleistocene have been identified in Miocene rocks as well as from Recent seas, there are numerous other planktonic Foraminifera in the Gulf Coast and Caribbean Middle Tertiary which have not been found in sediments younger than Miocene. One must be careful, therefore, with lack of evidence; absence of one or even several species does not necessarily offer strong evidence of a particular age. Even modern deep-sea sediments are known which contain abundant tests of certain planktonic species to the exclusion of others. As pointed out above, comparison with Pliocene assemblages is difficult because of the paucity of Pliocene pelagic facies which have been studied. All the planktonic species and subspecies of the post-Aftonian sediments (Akers and Holck, 1957) occur in the Gulf of Mexico and the Atlantic Ocean. The slightly different composition of the Aftonian and late Nebraskan planktonic assemblages is not surprising.

Some samples contained abundant tests of Foraminifera recognizable as planktonic but too small to identify to species. Juvenile similarity and morphological intergradation among the Globigerinidae are common in deep-sea samples (Bé, 1959, pp. 83-84, text-figure 1), and it was thought advisable to log these minute forms on our frequency chart (figure 3) as "planktonic indeterminants."

The writers are in agreement with Hofker (1959) on the splitting of planktonic genera and have applied his ideas in the systematic treatment of the globigerinids in this report. In so doing it is believed that a more realistic scheme is followed, which is more in keeping with the zoologist's restrictions on

nomenclature. These restrictions we believe to be not only possible but desirable in view of the fact that most of the Foraminifera treated herein are living today in modern seas. A return of several planktonic species to the original genera of d'Orbigny and Brady is proposed in our systematics, with the contention that splitting of these groups is based on an over-estimation of the significance of test feaures.

IV. Comparison of the Louisiana Pleistocene Assemblages with Other Foraminiferal Faunas of Pleistocene Age

The warm, shallow-water foraminiferal assemblages of Cushman (1918) and Cole (1931) from the Pleistocene and Pliocene of Florida are similar to some of the Pleistocene faunules from wells on the continental shelf off Louisiana, but the high frequency of planktonics and certain benthonics found in some of the intervals in deep continental shelf wells are not present in the Florida samples. Such components are also lacking in foraminiferal suites described from the Atlantic Coastal Plain of the United States (Bagg, 1898; Clark, 1906; Cushman and Cole, 1930). More similar is the suite of species identified by Drooger (1953) from a boring at Oranjestad, Aruba. Most of the species from this section, however, are considered by Drooger to be of Miocene age on the basis of "known stratigraphical ranges of the species," and only a few of the species and the upper part of the section are believed to represent Pleistocene deposition. His own criticism of the methods of age determination, however, leaves us with reservations as to the true age of the sequence on Aruba.

Gulf Coast Pleistocene assemblages are less similar to those of California than to Upper Miocene faunas of the Caribbean region. Cold water elements of the Pleistocene planktonic assemblages are much more in evidence in California than in the Gulf Coast. *Globigerina pachyderma* (Ehrenberg), for example, is abundant, and tests are large, in the Pleistocene of California, whereas specimens in the Louisiana Pleistocene are so small and rare as to be doubtfully identified with this species. *Globigerina bulloides* d'Orbigny is relatively more abundant in the West Coast Pleistocene than in the Gulf Coast; but some of the warm water planktonic species, such as *Globorotalia menardii menardii* and related forms which are frequent in the Gulf Coast-Caribbean region throughout Middle Miocene to Recent sediments, are rare or absent in the California section. Although a few benthonic species are common with the Louisiana and California Pleistocene, such as some of the *Cassidulina* spp. and *Uvigerina* spp., the West Coast Pleistocene has a different aspect in the presence of large forms restricted to the Pacific region.

Pleistocene assemblages from offshore Louisiana wells have few species in common with Pliocene and Pleistocene assemblages examined by van Voorthuysen (1950, 1953) from borings at the Hague and near Oosterhout. These borings did not encounter the numerous planktonic Foraminifera and the deep-water benthonic species characteristic of intervals in the Gulf Coast section believed to represent interglacial stages (Akers and Holck, 1957).

Many of the Louisiana Pleistocene Foraminifera occur in the Pliocene and Pleistocene of Italy. Some of these may be significant environmental and age indicators. *Hyalinea balthica* (Schroeter) has been found in rather high frequency in the Lower Pleistocene sediments of the Louisiana section. Heretofore, this benthonic form has been reported only from the Calabrian (Lower Pleistocene) of Italy and from the deep, cool waters of the eastern North Atlantic Ocean, the Baltic Sea, and the Mediterranean Sea. In Italy, the marine Pleistocene (Calabrian) is recognized and differentiated from marine Pliocene on the lowermost occurrence of this foraminifer and other cool water species (Alliata, 1946, 1947; Coggi and Alliata, 1950; Ilacqua, 1956). This practice is in keeping with the definition of the Plio-Pleistocene boundary at the 18th International Geological Congress of 1948 as the "time of the first appearance of 'cold' northern species of marine invertebrates (including *Hyalinea balthica*) in the continuous Plio-Pleistocene sequences of Italy." *H. balthica* in association with the planktonic *Globigerina inflata* and other Foraminifera suggests that Gulf of Mexico and Mediterranean environments were similar during the early Pleistocene and that, as expected, the Gulf of Mexico was colder than at the present time. Faunal similarity further suggests that these two basins were not isolated

from each other at least during the early Pleistocene.

V. Paleoecologic Considerations

The major ecologic implications of the cores from the South Pass Block 41 well have been discussed elsewhere (Akers and Holck, 1957, pp. 989-990). It was shown that intervals of deep water benthonics with a high planktonic component corresponded with marine transgressive tongues and that regressive wedges contained the benthonic assemblages characteristic of bays, lagoons, or brackish lakes. Inferences as to depositional environment are verified by the wealth of information published during the past ten years on the distribution of Foraminifera in the Gulf of Mexico, and we are tempted to postulate water depths and temperatures for suites of cores from the South Pass Block 41 well on the basis of our information on Recent species. Some of these data are given in our systematic section on forms which seem to be particularly diagnostic for certain environments. It is believed, however, that the relative changes in water depth represented in the previous report by Akers and Holck (1957, pl. 1) for the coastal Pleistocene are conservative deductions and that finer subdivisions might be speculative.

A. Frequency Chart

A frequency chart (figure 3) was constructed for those to whom quantitative data are significant; by means of the data shown thereon the interested investigator may draw his own conclusions regarding depositional environments. The chart also serves to supplement the ranges of Foraminifera previously unknown later than the Tertiary and others not previously identified in sediments older than Recent. Foraminiferal numbers (Schott, 1935) were computed for the core samples as a basis of comparison of populations. The term, foraminiferal number, is defined by Ellison (1951, p. 221) as the number of Foraminifera contained in one gram of dry original sediment or rock. This number is composed of a benthonic component and a planktonic component. The chart shows a total foraminiferal number, a benthonic foraminiferal number, and a planktonic foraminiferal number for each core. Frequency symbols are also shown with these numbers to facilitate recognition of fluctuating abundances on the chart. The same system of graphic representation is employed to depict the frequencies of individuals of the various species in each sample. The number of individuals of each species was computed for a single gram of each sample, but symbols were plotted rather than the actual figures for ease of interpretation.

The basic data used in computing foraminiferal occurrences are also charted for each core sample. For example, the sample at 412 feet weighed 8.29 grams (dry). After washing on a U.S. Standard Sieve, screen series No. 270, the residue weighing 0.02 grams (dry) was quartered by means of a microsplit for counting. The foraminiferal content of a gram of the sample was then computed on the basis of counts of individuals in one quarter of the sample. The degree of splitting was varied because of different characteristics of the samples. It was necessary to split some of the highly fossiliferous cores to 1/256, and even so, as many as 15 hours were sometimes spent by one of the authors in counting and tabulating specimens in the small aliquot. This small aliquot (in which the Foraminifera were actually counted) is shown for each sample in order for other interested investigators to better understand the nature of the data and consequent limitations.

All samples were washed on a No. 270 screen. The openings in this screen measure 0.0021 inches, or 0.053 mm. Thus, on the Wentworth scale, all particles with at least the dimensions of very fine sand and coarser silt were retained. The finer silt and clay size particules were discarded. It can be seen, then, by comparing the column of residue weights with the column of original weights, that the principal constituents of nearly all of the samples were of clay or fine to medium silt size.

The No. 270 screen retains a large percentage of "microforaminifera." Those of Wilson and Hoffmeister (1952) from "deep wells and Recent sediments" had dimensions of 30 to 150 microns. Our Pleistocene Foraminifera within this size category, like those of the above authors, belong mostly to the megalospheric generation of previously described species. Many of those minute tests consisted of only the proloculus or the initial two or three chambers. We do not believe that any species were overlooked because of insufficient magnification or excessive sieve openings, but the foraminiferal

number of a few of the samples would probably have been slightly larger if finer screens could have been used. Any additional tabulations would have been for indeterminant benthonics and planktonics, however, because accurate specific identifications can rarely be made by means of only the first few chambers.

It is interesting that four of the samples may be considered, by the definition of Correns, 1939, p. 375, as *Globigerina* ooze. According to this definition, a typical *Globigerina* ooze contains about 6000 specimens of planktonic Foraminifera (larger than 200 microns in diameter) per gram of sediment. The core at 578 feet contained (as computed) 6,359 planktonic specimens per gram, but 13,564 benthonic specimens per gram were also computed for it. The core at 3300 feet was the most fossiliferous sample obtained from the entire well. It was computed to have a total of 76,722 specimens of Foraminifera per gram, of which 40,812 were planktonic. The core at 3560 feet contained 17,344 specimens per gram, of which 10,726 were planktonic, and at 3574 feet a total of 25,452 specimens were computed to the gram, of which 16,223 were planktonic.

These last three samples are from the interval considered by Akers and Holck (1957, pl. 1) to represent the large scale marine transgression at the end of Nebraskan glaciation. It was also during this time that the cold water immigrant, *Hyalinea balthica,* was approaching its final occurrence in the Gulf of Mexico after appearing here for the first time in sediments of possible Calabrian age (9990 feet in the South Pass Block 41 well).

Other sedimentary cycles can be interpreted from the chart by those with experience in foraminiferal ecology. Generalizations as to post-Calabrian paleo-temperatures can also be made on the basis of foraminiferal associations, but the salient features of this section have already been described in the previous paper by Akers and Holck (1957).

Association in the Louisiana Pleistocene of cold-temperate and subtropical planktonic species may indicate (1) a mixing of tests from alternating seasons, or (2) allochthonous populations from different water masses.

VI. Recent Assemblages at the Well Site of the South Pass Block 41 Well

A Recent assemblage from the exact location of the South Pass Block 41 well (from which our suites of Pleistocene cores were taken) is described here for comparative purposes. The distribution and ecologic aspects of Foraminifera from this part of the Gulf of Mexico have been reported by Akers (1952), Bandy (1954, 1956), Kornfeld (1931), Parker (1954), Phleger (1954, 1955), and Warren (1956). A grab sample of the bottom sediments was taken in six feet of water at the well location for comparison with our Pleistocene assemblages. This sample, which was dark gray in color, was washed on a No. 270 screen, (U.S. Standard Sieve Series) as were the Pleistocene sidewall cores, and split by the same methods applied to the cores. Counts were made of the Recent Foraminifera in an aliquot portion and the foraminiferal number computed for the sample.

The weight of this grab sample (dry) was 15.6 grams. After screening, the weight of the residue was 1.9 grams. This small residue consisted of coarse, quartz silt (m.d., 0.05 mm), plant fibers (some carbonized), small Foraminifera, small, thin shelled pelecypods, ostracodes, diatoms, and mica flakes. The openings in the U.S. Standard Sieve No. 270 are 0.053 mm. Constituents of the original samples with dimensions less than this were not included in the study. Bottom sediments at the well site, as shown by this sample and others not included in our report, are largely of clay and silt size.

The foraminiferal number of the sample is 2085. No planktonic species were noted. The greater part of this number (1100) consists of *Ammonia beccarii* variants; 476 specimens belong to *Elphidium* spp., and 213 to miliolid species. Other species present in lesser frequencies are as follows:

Ammoscalaria pseudospiralis (Williamson)
Bolivina lowmani Phleger and Parker
Buliminella elegantissima (d'Orbigny)
Eponidella gardenislandensis Akers
Guadryina cf. *G. exilis* Cushman and Bronnimann
Guttulina australis d'Orbigny
Nonionella basiloba Cushman and McCulloch

Textularia earlandi Parker
Tiphotrocha comprimata (Cushman and Bronnimann)

Specimens of *Chiloguembelina cubensis* Palmer, undoubtedly reworked, were also found.

The arenaceous species found in this sample, *Ammoscalaria pseudospiralis, Gaudryina* cf. *G. exilis, Tiphotrocha comprimata,* and *Textularia earlandi,* are common in other near-shore localities in the Texas-Louisiana Gulf Coast. These species in association with other arenaceous Foraminifera have been found to be characteristic of sound, estuary, and marsh environments in both the Gulf Coast and the Caribbean region (Cushman and Bronnimann, 1948a; Cushman and Bronnimann, 1948b; Hedberg 1934; Lehmann, 1957; Phleger, 1954; Phleger, 1955; Post, 1951; Warren, 1956). The apparent absence of these arenaceous species from the thick Pleistocene sediments of coastal and offshore Louisiana is noteworthy and suggests that estuary, marsh, and possibly sound environments are not represented in our fossil record of Pleistocene events. It has been suggested, however, that the tests of these Foraminifera may be more susceptible to breakage or disaggregation with burial and compaction than are other fossils and that their absence in Pleistocene beds is due to their destruction. The latter argument is not convincing when confronted with Tertiary assemblages from coastal Louisiana wells with high frequencies of arenaceous species, some of which are identical with those found in modern marsh and estuary facies. The weight of our evidence indicates that the necessary combination of ecologic factors for the existence or accumulation of these arenaceous inshore assemblages did not persist here during the Pleistocene.

VII. Notes on Species and Descriptions of New Taxa

Throughout this report the neutral term, *form,* is used in the biologic connotation. In the sense of Mayr (1942, p. 108), "we often speak of a *form* when we do not know whether the systematic unit in question is, for example, a full species or merely a subspecies of a larger species, or whether it is a subspecies or an individual variant, or whether it is a subspecies or a phenotypical modification. We also use the term (in the plural) when we combine two unequal units; for example, in order to characterize the joint attributes of a species and a subspecies, we say 'these two forms'."

A total of 270 species and subspecies, or forms, were identified in this investigation. Ten of these have not previously been described, and with the exception of *Bolivina subaenariensis lucida,* n. subsp., have not been observed by the writers except in the Pleistocene or Pliocene of Louisiana. *Ammonia beccarii* is not subdivided here, and all specimens are grouped together as variants of that species. Several small miliolids of uncertain specific affinity have been tabulated in the frequency chart with the benthonic indeterminants. *Lenticulina* and the *Uvigerina* spp. probably have not been subdivided as much as some workers would consider feasible. It is not unlikely that more than 300 biologic forms of the Foraminiferida are present in the Gulf Coast Pleistocene and could be differentiated if larger samples comparable in size to those obtainable on outcrops were available. The total would be even higher if we include the section now thought to be Calabrian in age.

Other published occurrences, both stratigraphic and geographic, are given in the following discussion of species. In most instances authority for such occurrences is not cited for ease of reading and conservation of space. Literature consulted for this project is acknowledged in our introduction.

An alphabetical arrangement is followed for the presentation of genera and species rather than a phylogenetic system which is controversial and to many workers speculative. The writers do not mean to imply that evolutionary studies should not be done but only that an alphabetical order is more convenient for those who may wish to apply observations made in this paper to their own research.

All holotypes and paratypes will be deposited in the collection of the U. S. National Museum, Washington, D. C.

A. Planktonic Foraminifera

Globigerina aequilateralis H. B. Brady
Pl. XIII, figs. 1, 2

1879. *Globigerina aequilateralis* H. B. Brady, Quart. Journ. Micr. Sci., vol. 19, p. 71.
1884. *Globigerina aequilateralis* H. B. Brady, Rept. Voy. Challenger, Zool., vol. 9, p. 605, pl. 80, figs. 18-21.

As in Recent sediments of the Gulf of Mexico, most of our specimens are asymmetrical. The form illustrated by Brady, however, is included within the range of variation of Pleistocene and Recent specimens (See Phleger and Parker, 1951, p. 35). The species is recorded from Miocene to Recent in Mediterranean and Caribbean regions. Miocene references may include *Globorotalia obesa* Bolli. Maximum diameter of plesiotype, 0.35 mm.

GLOBIGERINA ALTISPIRA ALTISPIRA
Cushman and Jarvis
Pl. XII, figs. 3-5

1936. *Globigerina altispira* CUSHMAN and JARVIS, Contr. Cushman Lab. Foram. Res., vol. 12, p. 5, pl. 1, figs. 13, 14.

Pleistocene specimens are indistinguishable from types from the Miocene of Jamaica. The uppermost zone of the Gulf Coast Pleistocene in which this planktonic foraminifer has been found is the richly fossiliferous transgressive marine clays which have been correlated with the Williana Formation (Akers and Holck, 1957, Plates 1 and 3). The subspecies is also recorded from the Middle Tertiary of Haiti, Cuba, the Dominican Republic, the Balearic Islands, Italy and Louisiana. The senior writer has identified it in the Miocene of Florida and the Pliocene of Louisiana. Diameter of plesiotype, pl. XII, fig. 3, 0.46 mm; pl. XII, figs. 4, 5, 0.36 mm.

Dr. Mohsen-ul Haque, Deputy Director, Geological Survey of Pakistan, has observed *G. altispira altispira* in the Miocene and Pliocene of the Mekran coastal region of Pakistan (personal communication, April 12, 1958). There is a possibility that the Pliocene individuals were reworked, but such a condition has not been conclusively established, according to Dr. Haque. This foraminifer has also been observed in the Miocene of Taiwan, China.

The absence of *G. altispira* s.l. in recorded Pliocene assemblages of the world would suggest to some that the Pleistocene form may be of polyphyletic origin. Until a better understanding of relationships within this group is reached, however, the range probably should be considered as Lower Miocene to Lower Pleistocene. Specimens from Aruba may be of Pleistocene age instead of Miocene, as concluded by Drooger (1953). Our form may be related to Blow's specimens from the Upper Miocene of Venezuela to which he has given the name, *Globoquadrina pozonensis* (Blow, 1959, p. 184). An identical or closely allied form has been observed by the senior writer in the Manchioneal Formation (Pliocene?) of Portland, Jamaica, but it is not nearly so abundant there as is the form in the nearby Buff Bay beds (Upper Miocene?). An occurrence in the lowermost Pliocene of Sicily has been noted (Maria Bianca Cita, personal communication, April 29, 1960; Ruggieri, 1960, p. 11). The species has also been reported from the Lichi Formation (Miocene and Pliocene) of Taiwan (Chang, 1960, Table 1).

The locality at Milepost 71, Portland, Jamaica, which was recorded as the type by Cushman and Jarvis for *G. altispira,* was examined in 1957 by Mr. E. Robinson of the Geological Survey of Jamaica and the senior writer. Rocks here were found to contain abundant orbitoids rather than the expected planktonic assemblage, and due to the greater age and unlikely paleoecology of these sediments, it was concluded that Cushman and Jarvis erred in their locality records for *G. altispira.* Their specimens probably came from the Buff Bay Miocene locality.

GLOBIGERINA BRADYI Wiesner
Pl. XIII, figs. 8, 9

1884. *Globigerina* sp. H. B. BRADY, Rept. Voy. Challenger, Zool., vol. 9, p. 603, pl. 82, figs. 8, 9.

1901-1903. *Globigerina bradyi* WIESNER, Deutsche Sudpolar - Expedition, vol. 20 (Zool., vol. 12), p. 133 (for figs. see Brady *op. cit.*).

Specimens from the Louisiana Pleistocene rarely attain the high spired stage of typical specimens from Recent seas. Chamber arrangement, size, and apertural characteristics are close, however. This small species is reported from the Middle Tertiary of Trinidad, and it has been found by the senior writer in the Miocene of Louisiana. Diameter of plesiotype, 0.15 mm.

GLOBIGERINA BULLOIDES d'Orbigny
Pl. XIII, figs. 11, 12

1826. *Globigerina bulloides* D'ORBIGNY, Ann. Sci. Nat., vol. 7, p. 277, no. 1; Modèles, no. 76; and young, no. 17.

Specimens are small, rarely exceeding 0.30 mm in the greatest diameter. Size of aperture and number of chambers in final whorl are somewhat variable. Pleistocene speci-

mens definitely are within range of variation of the species, but care must be taken in differentiating between *G. bulloides* and the pre-orbuline stage of *Orbulina universa.* Diameter of plesiotype, pl. XIII, fig. 11, 0.36 mm. Diameter of plesiotype, pl. XIII, fig. 12, 0.34 mm.

Although this species has been reported widely throughout the stratigraphic column from Lower Cretaceous to Recent, critical study indicates that typical representatives did not appear before Middle or Upper Miocene (Bolli, 1954, p. 1). The species is not included by Bolli (1957) in his thorough report on planktonic Foraminifera of the Oligocene-Miocene Cipero and Lengua formations of Trinidad. The present writers have not authenticated pre-Pliocene occurrences in the Gulf of Mexico-Caribbean region. Rare specimens from the Choctawhatchee stage of Florida may be assignable to *G. bulloides,* but further study is required to settle this issue. It is possible that this cool water form was not typically developed in the Miocene Gulf of Mexico-Caribbean. Specimens from the Tortonian of the Vienna Basin are typical, however, as are specimens from the Helvetian or younger Miocene of the Balearic Islands, and an almost worldwide Pliocene distribution of the species seems to be properly documented.

GLOBIGERINA CONGLOBATA H. B. Brady
Pl. XII, figs. 9, 10

1879. *Globigerina conglobata* H. B. BRADY, Quart. Journ. Micr. Sci., vol. 19, p. 72.
1884. *Globigerina conglobata* H. B. BRADY, Rept. Voy. Challenger, Zool., vol. 9, p. 603, pl. 80, figs. 1-5; pl. 82, fig. 5.

Pleistocene specimens are typical of the form now living in the Gulf of Mexico and Atlantic Ocean. This group shows little variation. It is recorded in the Miocene of the Dominican Republic by Bermudez (1949, p. 280), and the senior writer has it from the Miocene of Jamaica and the Upper Miocene of Louisiana. *G. conglobata* is not recorded by Bolli (1957) from the Middle Tertiary Lengua and Cipero of Trinidad. Reports of the species from pre-Upper Miocene sediments may be misidentifications. It is abundant in the Pliocene (?) of Taiwan (Huang, 1960, Table 1). Diameter of plesiotype, 0.55 mm.

GLOBIGERINA EGGERI Rhumbler
Pl. XII, figs. 6-8

1879. *Globigerina dubia* H. B. BRADY (not Egger), Quart. Journ. Micr. Sci., vol. 19, n. ser., p. 71.
1884. *Globigerina dubia* H. B. BRADY, Rept. Voy. Challenger, Zool., vol. 9, p. 595, pl. 79, figs. 17a-c.
1900. *Globigerina eggeri* RHUMBLER, Nordische Plankton, pt. 14, Foraminiferen, p. 19, text figs. 20a-c.

A highly variable group is referred to this planktonic species. Both low and high turreted forms occur together in the cores. Gradational specimens present difficulty in subdividing the group on the basis of spire height. Asano (1957) was able to differentiate between *G. eggeri* and *G. subcretacea* Lomnicki on this basis in the Japanese seas and by the confinement of *G. eggeri* to the warm Kuroshio waters. Gulf Coast Pleistocene specimens are also variable in size, number of chambers in the final whorl, and in the aperture. In some specimens, the aperture has a peripheral lip. Small apertural teeth are present in some well-preserved specimens, suggesting relationship with *G. altispira.* Small apertural teeth have also been noted in Recent specimens from deep-sea sediments. Very young, tightly coiled specimens may be mistaken for *Globigerina pachyderma.* Low spired forms bear a marked similarity to *Globigerina mayeri* (Cushman and Ellisor). Thus at one extreme, there is resemblance to *Globigerina altispira* Cushman and Jarvis while the other extreme in variation approaches the form of *Globigerina mayeri.* The phylogenetic line is conjectural. Both *Globigerina altispira* and *Globigerina mayeri* occur in the Tertiary of the Gulf Coast and Caribbean regions, and both of these species appear to be related to *Globigerina eggeri.* Small specimens occur in the Louisiana Pliocene, but similar forms of pre-Pliocene age are closer to either *Globigerina mayeri* or *Globigerina altispira.* Diameter of plesiotype, 0.48 mm.

GLOBIGERINA GLUTINATA Egger
Pl. XIII, figs. 3, 4, 10

1893. *Globigerina glutinata* EGGER, K. bayer. Akad. Wiss., math.-physik. Cl., Abh., bd. 18, (1895) abth. 2, p. 371, pl. 13, figs. 19-21.
1909. *Globigerina glutinata* Egger. RHUMBLER, Plankton - Exped. Humboldt-Stift. 3:148, pl. 29, figs. 15, 18-20, 22, pl. 34, fig. 1 (not pl. 29, figs. 14, 16, 17, 21, 23-26, and not pl. 33, fig. 20).

1950. *Globigerinatella* aff. *insueta* Cushman and Stainforth. BRONNIMANN, Contr. Cushman Found. Foram. Res., vol. 1, pts. 3-4, p. 82, pl. 14, fig. 11.
1951. *Globigerinita naparimaensis* BRONNIMANN (part), Contr. Cushman Found. Foram. Res., vol. 2, pt. 1, p. 18, text figs. 3-14 (not text figs. 1-2).
1953. *Globigerinita glutinata* (Egger). PHLEGER, PARKER, and PEIRSON (part), Rept. Swedish Deep-Sea Exped., vol. 7 (1), p. 16, pl. 2, fig. 15 (not figs. 12-14).
1954. *Globigerinita naparimaensis* BRONNIMANN. Conato, Riv. Ital. Paleon. Strat., vol. 60, (1), p. 30, pl. 3, figs. 1-12.
1954. *Globigerinita glutinata* (Egger). PARKER, Harvard, Bull. Mus. Comp. Zool., vol. 111, no. 10, p. 477.
1955. *Globigerinita incrusta* AKERS, Journ. Paleontology, vol. 29, no. 4, p. 655, pl. 65, figs. 2A-2D.
1957. *Tinophodella ambitacrena* LOEBLICH and TAPPAN, Journ. Washington Acad. Sci., vol. 47, no. 4, p. 114, figs. 2a-3c.

Small specimens belonging to this rather variable planktonic species are found in the Gulf Coast in marine sediments from Miocene to Recent. There seem to be no significant differences between the Miocene specimens and those found living in the Gulf of Mexico and other waters. The supplementary chamber or umbilical cover plate is variable in size, number of apertures, and character of perforations. This chamber may be bulbous in some specimens and absent in others. Because of its small size, the species may have been disregarded or overlooked by many Tertiary workers, and it probably is worldwide in distribution. Diameter of plesiotypes, pl. XIII, fig 10, 0.28 mm; figs. 3, 4, 0.20 mm.

GLOBIGERINA INFLATA d'Orbigny
Pl. XIII, figs. 17-19

1839. *Globigerina inflata* D'ORBIGNY, *in* BARKER-WEBB and BERTHELOT, Hist. Nat. Iles Canaries, vol. 2, pt. 2, "Foraminifères," p. 134, pl. 2, figs. 7-9.

Fossil specimens are typical of the species. A few individuals were found at 3560 feet in the South Pass Block 41 well which have a final small chamber similar to that in *Globigerina nipponica* Asano. We have insufficient material to differentiate these two species. Diameter of plesiotype, 0.42 mm.

We have found *G. inflata* in the South Pass Block 41 well as deep as 9440 feet (Calabrian?), but presence of the species in beds older than this has not been substantiated. Colom (1954, p. 49) has been unable to verify its presence in the Mediterranean region before Pleistocene time, although Zei (1955, p. 536) reports it in the Pliocene as well as in the Calabrian of Italy. Chang (1960, Table 1) indicates that the species is found in beds of both Pleistocene and Pliocene age in Taiwan. Occurrence in the Liuchiuhsu mudstone (Pliocene?) of Taiwan is confirmed by Huang (1960, Table 1).

GLOBIGERINA cf. G. PACHYDERMA (Ehrenberg)
Pl. XIII, fig. 6

1861. *Aristerospira pachyderma* EHRENBERG, Monatsbericht k. preuss. Ak. Wiss. Berlin, p. 303.
1872. *Aristerospira pachyderma* EHRENBERG, (1873) Abhandl. d. k. Akad. Wiss. Berlin, p. 386, pl. 1, fig. 4.

Small specimens, less than 0.20 mm in diameter, resemble the cold water *G. pachyderma.* The large size of typical specimens of this species from the North Atlantic is not attained by Gulf Coast specimens, and it is possible that most, if not all, of these small forms are juveniles of other planktonic species, possibly of *Globigerina eggeri* Rhumbler. The specimen figured is the largest found in our material, and the closest to *G. pachyderma.* Maximum diameter of plesiotype, 0.19 mm.

The small size of this globigerinid and its similarities to other larger species suggest that it is a paedomorphic form, even in Recent seas, in which either directly or indirectly as a result of ecologic conditions the early developmental stage of the test has been retained during maturity.

GLOBIGERINA PARKERAE (Loeblich and Tappan)
Pl. XIII, fig. 5

1909. *Globigerina lamellosa* Terquem. RHUMBLER (not Terquem, 1882), Ergeb. Plankton - Exped. Humboldt-Stift 3: pl. 30, figs. 1-6.
1954. *Globigerina* sp. PARKER, Harvard, Bull. Mus. Comp. Zool. 111 (10) : 476.
1957. *Globigerinita parkerae* LOEBLICH and TAPPAN, Journ. Washington Acad. Sci., vol. 47, no. 4, p. 113, figs. 1a-c.

Our small Pleistocene specimens fall within the range of variation of Recent specimens from the Gulf of Mexico. The senior writer collected this species from the Mio-

cene Buff Bay locality in Jamaica, and it has been observed in the Upper and Middle Tertiary of the Gulf Coast. Diameter of plesiotype, 0.21 mm.

GLOBIGERINA RUBRA d'Orbigny
Pl. XII, figs. 11, 12

1839. *Globigerina rubra* D'ORBIGNY *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 82, pl. 4, figs. 12-14.
1880. *Globigerina gomitulus* SEGUENZA, Mem. Acc. Lincei, (3) VI, p. 228, t. XVII, ff. 16, 162.
1927. *Globigerina cyclostoma* GALLOWAY and WISSLER, Journ. Paleontology, vol. 1, no. 1, p. 42, pl. 7, figs. 8, 9.

Specimens belonging to this species can usually be recognized by the height of the final chamber, the position of the aperture, and the character of the wall. Variations are seen, however, in the size and shape of the test, number of chambers in the final whorl, and in the size and shape of the aperture. These variations seem to be shown by the species everywhere that it is recorded. Diameter of plesiotype, pl. XII, fig. 11, 0.44 mm; pl. XII, fig 12, 0.32 mm.

In addition to the typical form, elongate specimens are often found. These appear to belong with *Globigerina elongata* d'Orbigny. We are undecided as to whether this is an individual variation or whether it should be considered of subspecific or even specific rank.

GLOBIGERINA TRILOBA Reuss
Pl. XIII, figs. 15, 16

1850. *Globigerina triloba* REUSS, Denkschr. Akad. Wiss. Wien, vol. 1, p. 374, pl. 47, fig. 11.
1877. *Globigerina sacculifera* H. B. BRADY, Geol. Mag., vol. 4, p. 535.
1879. *Globigerina sacculifera* H. B. BRADY, Quart. Journ Micr. Sci., vol. 19, p. 73.
1884. *Globigerina sacculifera* H. B. BRADY, Rept. Voy. Challenger, Zool., vol. 9, p. 604, pl. 80, figs. 11-17; pl. 82, fig. 4.

This species is interpreted to include forms with the sac-like final chamber observed in some specimens as well as forms in which this type of chamber is not developed. The group may be recognized by the sphericity of the later chambers (excluding the sac-like chamber), the position of the aperture with respect to earlier chambers, and the character of the wall which is more coarsely punctate than in most other planktonic species. Diameter of plesiotype, 0.53 mm.

As in Recent and Tertiary sediments, Pleistocene specimens with and without this sac-like chamber (probably a reproductive stage) coexisted.

GLOBIGERINA UNIVERSA (d'Orbigny)
Pl. XIII, fig. 7

1839. *Orbulina universa* D'ORBIGNY *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères", p. 3, pl. 1, fig. 1.
1846. *Globigerina bilobata* D'ORBIGNY, Foraminifères fossiles du bassin tertiaire de Vienne, p. 164, pl. 9, figs. 11-14.
1941. *Orbulina bilobata* (d'Orbigny). PALMER, Mem. Soc. Cubana Hist. Nat., vol. 15, p. 286, pl. 28, fig. 3.
1951. *Orbulina suturalis* BRONNIMANN, Contr. Cushman Found. Foram. Res., vol. 2, part 4, p. 135, text-fig. 2, figs. 1-2, 5-8, 10; text-fig. 3, figs. 3-8, 11, 13-16, 18, 20-22; text-fig. 4, figs. 2-4, 7-12, 15-16, 19-22.
1956. *Biorbulina bilobata* (d'Orbigny). BLOW, Micropaleontology, vol. 2, no. 1, pp. 69-70, text-fig. 2, no. 16.

The *"Orbulina suturalis"* and *"Biorbulina"* forms of various authors are present in very low frequencies. The typical *G. universa* form is abundant in deep water intervals throughout the Pleistocene. This planktonic species has almost universal distribution in Middle and Upper Tertiary sediments, as well as in Recent seas.

We hold with Hofker (1959, p. 8) that *Orbulina* and *Biorbulina* forms are reproductive stages of other globigerines and have no value as genera. It is not unlikely that all of these forms, to which various specific names have been given by as many authors, represent the variable reproductive stages of a single long-ranging globigerine species. Diameter of plesiotype, 0.46 mm.

GLOBOROTALIA HIRSUTA (d'Orbigny)
Pl. XIV, figs. 6-9

1839. *Rotalina hirsuta* D'ORBIGNY *in* BARKER-WEBB and BERTHELOT, Hist. Nat. Iles Canaries, vol. 2, pt. 2, "Foraminifères", p. 131, pl. 1, figs. 37-39.
1953. *Globorotalia hirsuta* (d'Orbigny). PHLEGER, PARKER and PEIRSON, Repts. Swedish Deep-sea Exped., 1947-1948, vol. VII, Fasc. 1, p. 19, pl. 4, figs. 1-7.

The criteria of Phleger, Parker, and Peirson in the above reference are followed for recognizing this planktonic species. Forms

which are biconvex are referred to *G. hirsuta.* Similar forms which are plano-convex are referred to *G. punctulata* (d'Orbigny). The close relationship between these two species groups as suggested in this reference is supported by our Pleistocene material. In some cases, however, separation is arbitrary. Typical specimens of *G. hirsuta* occur in the "upper marine beds" (Akers and Holck, 1957, pls. 1 and 3). Diameter of plesiotype, pl. XIV, figs. 8, 9, 0.27 mm; pl. XIV, figs. 6, 7, 0.34 mm.

This species occurs in the subsurface Miocene of Louisiana and in the Choctawhatchee stage of the Florida Miocene. It has been identified in the Caribbean Miocene under various other names and is probably the form referred to by Drooger (1953, p. 143) as *Globorotalia canariensis* (d'Orbigny) from the Pleistocene and supposed Miocene of Aruba. The senior writer has also seen the species in the Pliocene of Italy and the Miocene Suva of Fiji.

Globorotalia menardii menardii
(d'Orbigny)

Pl. XIV, figs. 10-15; Pl. XII, figs. 13-15

1826. *Rotalia menardii* d'Orbigny, Ann. Sci. Nat., vol. 7, p. 273, no. 26; Modèles no. 10.

1884. *Pulvinulina menardii* (d'Orbigny). H. B. Brady, Rept. Voy. Challenger, Zool., vol. 9, p. 690, pl. 103, figs. 1, 2.

This planktonic group has variable characteristics, some of which are size, thickness of the test, thickness of the keel, number of chambers in the final whorl, inflation of the chambers on the umbilical side, lobulation of the periphery, and direction of coiling. The coiling direction is over 90% sinistral throughout the Pleistocene of the Gulf Coast, except for a zone near the base of the "upper marine beds". In this interval, specimens distinct from *G. menardii miocenica* are invariably dextral. Diameter of plesiotype, pl. XII, figs. 13-15, 0.70 mm; pl. XIV, figs. 12, 13, 0.44 mm; pl. XIV, figs. 10, 11, 0.34 mm; pl. XIV, figs. 14, 15, 0.57 mm.

The literature contains numerous "identifications" of this form in beds of pre-Pleistocene age. Both literature and samples have been examined by the senior writer, and in no case has a pre-Pleistocene specimen attained the large size observed in Recent and Pleistocene individuals. Large related *Globorotalia* in South American and Pacific Tertiary sediments invariably differ in the number of chambers or (and) the height of the spire. Among these have been described *G. menardii multicamerata* Cushman and Jarvis, *G. menardii tumida* (H. B. Brady), and *G. menardii fijiensis* Cushman. Small forms from the Upper Miocene of the Gulf Coast, Venezuela, and Trinidad which have been grouped under *G. menardii menardii* seldom exceed half the diameter of large, compressed Recent specimens. Whether these larger, more oblong forms are actually descended from Upper Miocene *Globorotalia*s presently included in the same taxon rather than arising from another group such as *G. menardii tumida, G. menardii fijiensis,* or *G. menardii multicamerata* is only speculative. Indeed, variation observable in *G. menardii menardii* in modern seas is not well understood, and it is not improbable that the group is polyphyletic.

Globorotalia menardii miocenica
D. K. Palmer

Pl. XIV, figs. 1-5; 19-21

1945. *Globorotalia menardii* (d'Orbigny) var. *miocenica* D. K. Palmer, Bull. Amer. Paleontology, vol. 29, no. 115, p. 70, pl. 1, fig. 10.

This form is not usually found above the lower part of the "upper marine beds" (Akers and Holck, 1957, pls. 1 and 3) of coastal and offshore Louisiana. The frequency of the subspecies in this part of the Lower Pleistocene is a criterion for recognizing regional stratigraphic position by means of well samples. A few small specimens have been found higher in the Pleistocene section (one at 1270, one at 1436, one at 1454, and one at 1609 feet in the South Pass well).

Approximately 200 topotypes from the Miocene of Jamaica were examined for comparison with Louisiana Pleistocene specimens. About 90 per cent of these Jamaican specimens are flat on the spiral side and have a high umbilical side. The remainder are bi-convex. In our Pleistocene samples, this relationship varies. In some of the assemblages approximately 90 per cent of the specimens are plano-convex. In other samples, the majority of the specimens are biconvex with only occasional plano-convex specimens. As in the Miocene Jamaican assemblages, however, all specimens observed are coiled dextrally. Diameter of plesiotype, pl. XIV, figs. 19-21, 0.48 mm; pl. XIV, figs.

3-5, 0.47 mm; pl. XIV, figs. 1, 2, 0.40 mm.

Specimens approximating the form of *G. menardii miocenica* and also dextrally coiled are found in the Choctawhatchee Stage of the Florida Miocene and in well samples from the Pliocene and Upper Miocene of coastal and offshore Louisiana. This foraminifer is also reported from the Upper Miocene of Morocco and the Dominican Republic, and typical specimens have been examined from cores in 3570 meters of water off the eastern coast of the United States (D. B. Ericson, personal communication). This latter occurrence and the occurrences in Aruba assumed by Drooger (1953) to be Miocene may be of Pleistocene age.

GLOBOROTALIA MENARDII MULTICAMERATA
Cushman and Jarvis
Pl. XIV, figs. 22-25

1930. *Globorotalia menardii* (d'Orbigny) var. *multicamerata* CUSHMAN and JARVIS, Journ. Paleontology, vol. 4, no. 4, p. 367, pl. 34, fig. 8.

Occasional specimens are found with *Globorotalia menardii miocenica* in the "upper marine beds" of the Gulf Coast Pleistocene. In these samples, it is possible that such forms are aberrant individuals of the *Globorotalia menardii miocenica* group. Both forms are always dextrally coiled, and they are similar in convexity. Topotypes of *G. menardii multicamerata* from the lowest zone of the Buff Bay Formation of Jamaica are also invariably dextral, but the keel is variable in thickness. Jamaican specimens may easily be separated into a thick-keeled group and a thin-keeled group. A higher zone in the Buff Bay Formation yields forms collected by the senior writer which are predominantly thin-keeled and sinistrally coiled, the ratio being 12:1 in favor of sinistral coiling. Diameter of plesiotype, pl. XIV, figs. 22, 23, 0.55 mm; pl. XIV, figs. 24, 25, 0.94 mm.

There is similarity between the individuals of this group and *Globorotalia menardii fijiensis* Cushman from the Miocene Suva of the South Pacific Region. The *Globorotalia menardii fijiensis-multicamerata* observed by Stainforth (1948, p. 125) in the Miocene of Ecuador also seems to belong to the same group. The relationship of these *Globorotalias* to *Globorotalia fohsi lobata* Bermudez, another similar Miocene planktonic, is further interesting and poorly understood. The single occurrence reported from Recent sediments north of Cuba (Cushman and Bermudez, 1949, p. 30) is probably of Tertiary or Pleistocene age. Presence of this form in Recent sediments has not been authenticated.

GLOBOROTALIA MENARDII TUMIDA
(H. B. Brady)
Pl. XIV, figs. 26-28

1877. *Pulvinulina menardii* d'Orbigny var. *tumida* H. B. BRADY, Geol. Mag., vol. 4, p. 294.
1884. *Pulvinulina tumida* H. B. BRADY, Rept. Voy. Challenger, Zool., vol. 9, p. 692, pl. 103, figs. 4-6.

Forms are found in the Pleistocene cores which appear to be intermediate between *Globorotalia menardii menardii* and *Globorotalia menardii tumida* of Recent samples. Some of the thicker specimens may be assigned to *G. menardii tumida.* This variation within the *Globorotalia menardii* group seems to have begun before the Pleistocene. D. B. Ericson (personal communication) identified *G. menardii tumida* in Pleistocene cores from the Atlantic and Caribbean. *Globorotalia menardii tumida* is reported from Saipan in rocks for which a Miocene age has been assumed (Todd, 1957). In Taiwan the range has been reported as Miocene through Pleistocene (Chang, 1960, Table 1). The form is abundant in the Pliocene (?) Liuchiuhsu mudstone of Taiwan (Huang, 1960, Table 1), and the senior writer has it from the Miocene (?) Suva.

GLOBOROTALIA PUNCTULATA (d'Orbigny)
Pl. XIII, figs. 20-22

1826. *Globigerina punctulata* D'ORBIGNY, Ann. Sci. Nat., vol. 7, p. 277, no. 8.
1898. *Globigerina punctulata* d'Orbigny. FORNASINI, Paleont. Ital, vol. 4, p. 210, text. fig. 5.
1953. *Globorotalia punctulata* (d'Orbigny). PHLEGER, PARKER, and PEIRSON, Repts. Swedish Deep-Sea Exped., 1947-1948, vol. VII, Fasc. 1, p. 20, pl. 4, figs. 8-12.

This species was found in marine sediments throughout the Pleistocene. Similarity to *G. hirsuta* is discussed under that species. An excellent synonymy is contained in the reference above by Phleger, Parker, and Peirson. Maximum diameter of plesiotype, 0.60 mm; thickness, 0.34 mm.

G. punctulata has been identified by the senior writer in the *Ecphora* Facies, Choctawhatchee Stage, of the Florida Miocene. It is uncommon in the subsurface Miocene of Louisiana. The species is also reported from the Miocene of Jamaica and Taiwan and the Pliocene and Pleistocene of Italy.

GLOBOROTALIA TRUNCATULINOIDES
(d'Orbigny)
Pl. XIV, figs. 16-18

1839. *Rotalina truncatulinoides* D'ORBIGNY *in* BARKER-WEBB and BERTHELOT, Hist. Nat. Iles Canaries, vol. 2, pt. 2, "Foraminifères", p. 132, pl. 2, figs. 25-27.

As in Recent sediments, the species has variable characteristics. The periphery varies from acute to rounded. The umbilicus may be almost closed or it may be open. The thickness is perhaps the most variable characteristic. The spiral side is always flat, but the umbilical side varies from almost flat to extremely high. Thick specimens are readily recognized as belonging to this group, but low specimens are easily confused with *Globorotalia menardii miocenica, G. hirsuta,* and *G. punctulata.* The species is present in marine zones throughout the Gulf Coast Pleistocene. Maximum diameter of plesiotype, 0.55 mm.

G. truncatulinoides is recorded from the Pleistocene and Upper Pliocene of Italy. We have also seen it in the Louisiana Pliocene, but pre-Pliocene evidence for the species seems to be lacking. It is also listed by Chang in the Pliocene and Pleistocene of Taiwan. It is abundant in the Pliocene (?) Liuchiuhsu Mudstone of Taiwan (Huang, 1960, Table 1).

This species was examined for coiling ratios in cores throughout the Pleistocene of the South Pass Block 41 well. Shifts in coiling dominance in deep-sea cores from the North Atlantic and adjacent seas have been useful for correlation (Ericson, D. B., G. Wollin, and J. Wollin, 1954; Ericson, D. B., 1961, p. 538). We were surprised and disappointed to find that *G. truncatulinoides* is dominantly dextral in every core where it was identified by us. Either this portion of the northern Gulf of Mexico remained a province in which the species was dominantly dextral throughout the Pleistocene, or sinistral preferences existed here but were not observed due to inadequate sampling of the well. It is possible, too, that planktonic-poor intervals, though thoroughly sampled, may be correlative with nearby sediments in which sinistral shifts are present.

PULLENIATINA OBLIQUILOCULATA
(Parker and Jones)
Pl. XII, figs. 1, 2

1865. *Pullenia obliquiloculata* PARKER and JONES, Phil. Trans., vol. 155, p. 368, pl. 19, figs. 4a, b.

This planktonic species is known from Upper Miocene to Recent sediments. It is reported from the Pliocene of Panama, Pliocene and Upper Miocene of the Netherlands East Indies, Pliocene and Pleistocene of Taiwan, and from the Upper Miocene of the Dominican Republic. Diameter of plesiotype, 0.42 mm.

SPHAEROIDINELLA DEHISCENS
(Parker and Jones)
Pl. XIII, figs. 13, 14

1865. *Sphaeroidina dehiscens* PARKER and JONES, Phil. Trans., vol. 155, p. 369, pl. 19, figs. 5a-c.

This Miocene to Recent planktonic species is recorded in the Miocene of Louisiana, Jamaica, Haiti, and the Dominican Republic and from the Pliocene of Italy and Taiwan. Maximum diameter of plesiotype, pl. XIII, fig. 13, 0.50 mm; pl. XIII, fig. 14, 0.63 mm.

B. BENTHONIC FORAMINIFERA

ALVAREZINA BRADYI (Cushman)
Pl. I, fig. 22

1911. *Gaudryina bradyi* CUSHMAN, U. S. Natl. Mus., Bull. 71, pt. 2, p. 67, text figs. 107a-c.

1949. *Karreriella bradyi* (Cushman). BERMUDEZ, Cushman Lab. Foram. Res., Spec. Publ. 25, p. 89-90, pl. 5, figs. 11-16.

This species is not recorded shallower than 155 meters nor deeper than about 800 meters in the Gulf of Mexico according to Phleger (1951, p. 47). Bermudez in the reference above gives a complete synonymy and records the species from "the whole of the Tertiary of the Dominican Republic". This species is recorded from both the Atlantic and the Pacific Oceans as well as from various Caribbean Tertiary localities. It has also been reported from the Miocene of the Balearic Islands, the Alazan beds of Mexico, and from Lower Eocene to Quaternary of Italy. Length of plesiotype, 0.48 mm; breadth, 0.30 mm; thickness, 0.29 mm.

This form is listed in figures 2 and 3 as *Karreriella bradyi* (Cushman).

ALVAREZINA CYCLOSTOMATA SINUATA
Akers and Dorman, n. subsp.
Pl. II, figs. 1, 2

The subspecies differs from the typical only in that the aperture is an elongate, narrow, strongly curved, sometimes sigmoidal slit rather than a circular or elliptical opening. The aperture in our Pleistocene forms has a thin low lip, whereas the apertural lip in *A. cyclostomata* (Galloway and Morrey) is thick, high, and almost a neck.

Holotype and paratype of the subspecies are from a core at 2420 feet in The Texas Co., Delta Duck Club, Unit 2, Well 1-A, Sec. 1, T21S, R19E, Plaquemines Parish, Louisiana. Dimensions of holotype: length, 0.95 mm; breadth, 0.84 mm. Length of paratype, 0.65 mm; breadth, 0.50 mm.

The primary types of *Alvarezina mexicana* (Nuttall) from the Tertiary of Mexico and *A. barbati* (Cushman) from the Tertiary of California were compared. Cushman's holotype and paratype belong to two distinct species, possibly to different genera. His paratype is identical with the holotype of Nuttall.

Hundreds of specimens from the Louisiana Oligocene and Miocene were examined. These are referred by some Gulf Coast paleontologists to *A. mexicana* (Nuttall), but it was found that the aperture in these forms is variable. At one extreme, it is circular, as in *A. cyclostomata;* at the other it is elongate-elliptical, sometimes gently curved. In all cases, the opening has a thickened lip which is never so low or contorted in shape as in the Pleistocene form.

A. mexicana must be considered as a synonym, or at most, as a subspecies of *A. cyclostomata.* Apparent variations in test shape may be produced by compaction of the enclosing clays and shales.

This form is listed as *Karreriella cyclostomata sinuata* in figure 3.

This foraminifer with *Globorotalia menardii miocenica* seems to have become extinct in the Gulf of Mexico during the Aftonian. *A. cyclostomata* disappeared during the Pliocene or upper Miocene.

AMMONIA BECCARII (Linné) variants
Pl. X, figs. 14, 15

1758. *Nautilus beccarii* LINNÉ, Syst. Nat., ed. 10, p. 710.

The example of previous American workers is followed in assigning small specimens to *A. beccarii* (Linné) although these probably constitute a distinct species or several distinct species from the larger specimens in the Tertiary of the Mediterranean region. As in Recent sediments of the Gulf of Mexico, a high frequency of this group indicates deposition in shallow nearshore waters. Diameter of figured specimen, 0.29 mm.

AMPHICORYNA cf. A. INTERCELLULARIS
(H. B. Brady)
Pl. VI, fig. 4

1881. *Nodosaria intercellularis* H. B. BRADY, Quart. Journ. Micr. Sci., vol. 21, p. 63.
1884. *Nodosaria intercellularis* H. B. BRADY, Rept. Voy. Challenger, Zool., vol. 9, p. 515, pl. 65, figs. 1-4.

Our Pleistocene specimens usually consist of only two chambers. The type figure of *Nodosaria catesbyi* (shore sands of Cuba) shows 14 costae. That of *Nodosaria spinicosta* (Vienna Basin) shows 18. Our specimens have 20 to 22 longitudinal costae. Our form seems closer to this Recent Atlantic and Caribbean species than to any other species of *Amphicoryna* or *Nodosaria.* Length of figured specimen, 0.40 mm; diameter, 0.19 mm.

This form is listed in figure 3 as *Nodosaria* cf. *N. intercellularis* H. B. Brady.

AMPHISTEGINA LESSONII d'Orbigny
Pl. XI, figs. 32, 33

1826. *Amphistegina lessonii* D'ORBIGNY, Ann. Sci. Nat., vol. 7, p. 304, no. 3, pl. 17, figs. 1-4, Modèles no. 98.

In Pleistocene beds, this species is restricted to calcareous zones. Phleger and Parker (1951, p. 26) report it as rare in Recent sediments of the Gulf of Mexico, except in calcareous areas. Pleistocene specimens show variations similar to Recent specimens in thickness of test and size of umbo. Our specimens are referred to d'Orbigny's species (Recent of Mauritius) in the absence of a satisfactory means of subdividing the group. Maximum diameter of plesiotype, 0.95 mm.

A. lessonii has been recorded from the Miocene of Florida, Louisiana, South Caro-

lina, North Carolina, Virginia, Venezuela, Haiti, Jamaica, and the Dominican Republic, and from the Upper Oligocene of Cuba. This form probably has world-wide distribution in Middle Tertiary and younger beds. It is reported throughout the Italian post-Paleocene Tertiary and from the Pleistocene of Aruba.

Additional investigation may indicate reference of this form to *A. gibbosa* d'Orbigny (see Barker, 1960, p. 228).

ANOMALINOIDES IO (Cushman)
Pl. XV, figs. 9, 10

1931. *Cibicides pseudoungeriana* (Cushman) var. *io* CUSHMAN (part), U. S. Natl. Mus., Bull. 104, pt. 8, p. 125, pl. 23, fig. 1 (not fig. 2).

Pleistocene specimens are very close to Recent forms from the Gulf of Mexico which have been referred to this species by Parker (1954). Maximum diameter of plesiotype, 0.36 mm; thickness, 0.14 mm.

The species has been reported from the Miocene of coastal Louisiana, Cuba, Haiti, Puerto Rico, and the Dominican Republic and from the Upper Oligocene (?) and Pliocene of Cuba.

This form is listed in figures 2 and 3 as *Cibicides io* Cushman.

ARCHAIAS ANGULATUS (Fichtel and Moll)
Pl. VII, fig. 30

1798. *Nautilus angulatus* FICHTEL and MOLL, Testacea microscopica aliaque, minuta ex generibus Argonauta et Nautilus, Wien, Osterreich, p. 113, pl. 22, figs. a-e.
1839. *Orbiculina compressa* D'ORBIGNY *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères", p. 66, pl. 8, figs. 4-7.
1930. *Archaias angulatus* (Fichtel and Moll). CUSHMAN, U. S. Natl. Mus., Bull. 104, pt. 7, p. 46, pl. 16, figs. 1-3; pl. 17, figs. 3-5.
1956. *Archaias angulatus* (Fichtel and Moll). BANDY, U. S. Geological Survey Professional Paper 274-G, p. 192.

Although *Archaias compressus* (d'Orbigny) and *A. angulatus* (Fichtel and Moll) seem to be distinct in some assemblages, Bandy, in the above reference, has pointed out that growth sequences show *A. angulatus* to be quite variable, depending on size. However, Cushman, in his reference above, believed the two to be separate and recommended a study involving the relationships of microspheric and megalospheric forms by means of sections. Pending such a definitive investigation, *A. angulatus* will be interpreted as including other species and varieties of various authors.

This species occurred most frequently in the interval 592-610 feet in the South Pass Block 41 well. Maximum diameter of plesiotype, 1.43 mm.

A. angulatus has been reported from the Tertiary of Puerto Rico and the Dominican Republic. The range of the species appears to be Middle Oligocene to Recent (Bermudez, 1949, p. 174). In Cuba it occurs throughout the section above Middle Oligocene (Jaruco) according to Bermudez (1950, p. 328).

ARTICULINA AURICULATA (Egger)
Pl. II, fig. 20

1893. *Planispirina auriculata* EGGER, Abhandl. k. bay. Akad. Wiss. München, vol. 18, pt. 2, p. 245, pl. 3, figs. 13-15.
1954. *Wiesnerella auriculata* (Egger). PARKER, Harvard, Bull. Mus. Comp. Zool., vol. 111, no. 10, p. 501, pl. 5, fig. 13.

Our Pleistocene species seems to be the same as that reported by Parker in the above reference from the northeastern Gulf of Mexico. This is very close to Egger's figures of specimens from the Indian Ocean. Coloration in the species is striking and variable. Some specimens are white. Others are white for the most part but with a black rim around the apertural area. In some specimens only the costae are black, and these may be either numerous and closely spaced or few and widely spaced. Still other specimens are entirely black. The writers observed specimens which become rectilinear. Length of plesiotype, 0.44 mm; breadth, 0.27 mm.

ARTICULINA MAYORI Cushman
Pl. III, figs. 8-10

1922. *Articulina mayori* CUSHMAN, Carnegie Inst. Washington, Publ. no. 311, p. 71, pl. 13, fig. 5.

Only two small broken specimens (at 610 feet) were found in the South Pass Block 41 well. These show the faint costae typical of the species. This foraminifer is also recorded from the Miocene Chipola Facies of the Florida panhandle. Length of fragment, pl. III, fig. 8, 0.34 mm. Length of fragment, pl. III, figs. 9, 10, 0.38 mm.

ARTICULINA PAUCICOSTATA Cushman
Pl. III, fig. 11

1944. *Articulina paucicostata* CUSHMAN, Cushman Lab. Foram. Res., Spec. Publ. 10, p. 14, pl. 3, figs. 13, 14.

Only two specimens (at 610 feet) were found in the South Pass Block 41 well. These are different from *A. mayori* in having considerably fewer and better developed costae. Our specimens are assigned to *A. paucicostata* although the costae are somewhat irregularly spaced and the number of costae slightly variable. Length of plesiotype, 0.46 mm.

ASTERIGERINA CARINATA d'Orbigny
Pl. XI, figs. 22, 23

1839. *Asterigerina carinata* D'ORBIGNY *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères", p. 118, pl. 5, fig. 25; pl. 6, figs. 1, 2.

All specimens of this genus from the Pleistocene of Louisiana seem to belong to a single species. It has been reported from the Miocene of Cuba, Jamaica, and the Dominican Republic and from the Pleistocene of Aruba. Diameter of plesiotype, 0.78 mm.

BIGENERINA IRREGULARIS Phleger and Parker
Pl. I, fig. 15

1951. *Bigenerina irregularis* PHLEGER and PARKER, Geol. Soc. America, Mem. 46, pt. 2, p. 4, pl. 1, figs. 16-21.

Pleistocene specimens show variations in size and mineralogy of grains as do Recent specimens, according to the above reference. It is possible that this group includes several varieties. The specimens from 2418 feet in the South Pass Block 41 well may belong to a different species, but, except for size, they seem to belong here. As in Recent sediments of the Gulf of Mexico, Pleistocene specimens from calcareous zones are composed of shell fragments rather than quartz grains. Length of plesiotype, 0.71 mm.

BIGENERINA TEXTULARIOIDEA (Goës)
Pl. I, figs. 16, 17

1894. *Clavulina textularioidea* GOES, Kongl. Svensk. Vet.-Akad. Handl., vol. 25, no. 9, p. 41, pl. 8, figs. 387-399.

As in *Bigenerina irregularis,* a variety of agglutinated materials is employed in the test. In some large specimens from calcareous zones, this material consists of the entire tests of calcareous Foraminifera. In these cases, the tests usually have a shiny, polished appearance.

An excellent synonymy is given by Bermudez (1949, p. 67). This foraminifer has been reported from the Recent of the Caribbean-Antillean region and the Gulf of Mexico and from the Miocene of Florida, Jamaica, the Dominican Republic, and Mallorca. In Cuba, the range is given as Middle Miocene to Recent. Length of plesiotype, pl. I, fig. 16, 0.97 mm; maximum breadth, 0.42 mm. Length of plesiotype, pl. I, fig. 17, 1.24 mm; maximum breadth, 0.73 mm.

BILOCULINELLA TODDAE Andersen
Pl. III, figs. 25-28

1961. *Biloculinella toddae* ANDERSEN, Louisiana Dept. Conserv., Geol. Bull. 35, pt. II, p. 41, pl. 9, figs. 6a, b.

Test small, biloculine in the adult, both chambers inflated, final chamber in some specimens enclosing all but a small rounded area of the next preceding chamber; apertural extremity of test slightly extended; aperture semi-elliptical in shape completely filled by a broad concave toothplate. Maximum diameter of plesiotype, pl. III, figs. 27, 28, 0.36 mm; pl. III, figs. 25, 26, 0.32 mm.

BOLIVINA ACEROSA Cushman
Pl. VIII, fig. 23

1936. *Bolivina acerosa* CUSHMAN, Cushman Lab. Foram. Res., Spec. Publ. 6, p. 54, pl. 8, fig. 1.

Several hundred specimens were found in a small sidewall core at 2580 feet in the South Pass Block 41 well. Well preserved individuals have clear areas at the upper and inner portion of each chamber. Wall character in this respect is similar to that in *Bolivina pacifica* Cushman, B. *translucens* Phleger and Parker, and *B. daggarius* Parker. Our specimens were compared with the holotype from the Gurabo Formation of the Dominican Republic with which they compare closely in test dimensions, number and arrangement of chambers, and pore arrangement.

The species has not been found in sediments younger than approximately Middle Pleistocene. It is also reported from Middle Tertiary beds of Cuba and Costa Rica. The writers have it from the Miocene Buff Bay locality, Jamaica, and from the Pliocene of Louisiana. This species is reported from beds in Aruba believed to be Miocene in age (Drooger, 1953), but which may be Pleis-

tocene. Length of plesiotype, 0.40 mm; breadth, 0.10 mm; thickness, 0.09 mm.

BOLIVINA ALATA (Seguenza)
Pl. VIII, fig. 24

1862. *Vulvulina alata* SEGUENZA, Atti Accad. Gioenia Sci. Nat., ser. 2, vol. 18, p. 115, pl. 2, figs. 5, 5a.

Pleistocene specimens from Louisiana show considerable variation in breadth, but this range of variation seems to be similar to the range of variation observed in specimens from Italy. Our Pliocene specimens from the vicinity of Cecina, Italy, are identical with some of the Louisiana individuals in all respects.

The holotype of the species is from the Pleistocene of Italy. Specimens are also recorded from the Recent of the Gulf of Mexico and the Miocene of Jamaica, Venezuela, the Dominican Republic, and Mallorca. Bagg (1904, p. 473) recorded this foraminifer from the Calvert Formation (Miocene) of Chesapeake Beach, Maryland. It ranges in Italy from Miocene to Recent. Length of plesiotype, 0.42 mm; breadth, 0.17 mm.

BOLIVINA ALBATROSSI Cushman
Pl. VIII, fig. 7

1922. *Bolivina albatrossi* CUSHMAN, U. S. Natl. Mus., Bull. 104, pt. 3, p. 31, pl. 6, fig. 4.

Some of the Pleistocene specimens appear to be identical with the holotype from off the Carolina coast (873 meters of water). There is variation in the reticulated nature of the test, however, some specimens being smooth throughout while others show reticulations throughout; others have only the early portion of the test marked by a network of fine reticulations.

According to Phleger and Parker (1951, p. 41), the species is especially characteristic of water deeper than about 200 meters in the Gulf of Mexico. In the South Pass Block 41 well, this species was most abundant within the interval 3104 feet to 3490 feet. *B. albatrossi* is also recorded from the Miocene of Jamaica. Specimens in our collection from Buff Bay are identical with those from Gulf Coast Recent and older sediments. Length of plesiotype, 0.36 mm; breadth, 0.16 mm.

BOLIVINA BARBATA Phleger and Parker
Pl. VIII, fig. 34

1951. *Bolivina barbata* PHLEGER and PARKER, Geol. Soc. America, Mem. 46, pt. 2, p. 13, pl. 6, figs. 12a, b, 13.

Pleistocene specimens are typical of the species. Length of plesiotype, 0.42 mm; breadth, 0.19 mm.

BOLIVINA CATANENSIS Seguenza
Pl. VIII, figs. 3, 21

1862. *Bolivina catanensis* SEGUENZA, Atti Accad. Gioenia Sci. Nat., ser. 2, vol. 18, p. 29, pl. 2, figs. 3, 3a, 3b.

Pleistocene specimens were compared with material from the Pliocene near Cecina, Italy. The Mediterranean forms reach a length of 0.6 mm whereas our specimens seldom exceed 0.3 mm. Recent specimens from the Gulf of Mexico are approximately the same size as the Louisiana Pleistocene forms. They are similar to *Bolivina goësii,* although the shape of the test is markedly different, being wider and more compressed in the latter. The species ranges from Miocene to Recent in the Mediterranean region. Types are from the Pleistocene of Catania, Sicily. Length of plesiotype, pl. VIII, fig. 3, 0.25 mm; breadth, 0.13 mm. Length of plesiotype, pl. VIII, fig. 21, 0.28 mm; breadth, 0.13 mm.

BOLIVINA DAGGARIUS Parker
Pl. VIII, fig. 22

1955. *Bolivina daggarius* PARKER, Contr. Cushman Found. Foram. Research, vol. 6, pt. 1, p. 52, pl. 31, fig. 9.

Only two specimens were found which are referable to this species. Length of plesiotype, 0.26 mm; breadth, 0.06 mm.

BOLIVINA DIFFORMIS (Williamson)
Pl. VIII, fig. 8

1858. *Textularia variabilis* Williamson var. *difformis* WILLIAMSON, Rec. Foram. Gt. Britain, p. 77, pl. 6, figs. 166, 167.
1937. *Bolivina difformis* (Williamson). CUSHMAN, Cushman Lab. Foram. Res., Spec. Publ. 9, pp. 164-165, pl. 15, figs. 13-17.

A single specimen, probably a juvenile, was found at 545 feet in the South Pass Block 41 well. The length of the specimen is only 0.19 mm; breadth, 0.13 mm. Numerous localities are given by Cushman in the above reference. Some of these are from the present waters about the British Isles northward to the coast of Norway, and possibly into the Mediterranean. There are also nu-

merous records for the species in the Pleistocene clays of England and Ireland.

BOLIVINA FRAGILIS Phleger and Parker
Pl. VIII, figs. 14, 26

1951. *Bolivina fragilis* PHLEGER and PARKER, Geol. Soc. America, Mem. 46, pt. 2, p. 13, pl. 6, figs. 14, 23, 24a, b.

This species is rare in the Gulf Coast Pleistocene. It is present in rather high frequencies in only two cores in the South Pass Block 41, well, 1100 feet and 2238 feet. Specimens at 3258 feet are not typical and may belong to another species.

Pleistocene specimens show considerable peripheral variation. Some, like the holotype, have a distinct keel, but others have a subacute periphery. There is also variation in the costae which are distinct in some individuals but faint to absent in others. Only a few of our specimens have a short spine at the initial end. Length of microspheric plesiotype, pl. VIII, fig. 26, 0.59 mm; breadth, 0.19 mm. Length of megalospheric plesiotype, pl. VIII, fig. 14, 0.42 mm; breadth, 0.18 mm.

BOLIVINA GOËSII Cushman
Pl. VIII, fig. 1

1922. *Bolivina goësii* CUSHMAN, U. S. Natl. Mus., Bull. 104, pt. 3, p. 34, pl. 6, fig. 5.

Pleistocene specimens are identical with Recent forms from the Gulf of Mexico including homeotypes of Phleger and Parker (1951, pl. 6, fig. 13). The species is also reported from the Miocene of the Dominican Republic. Length of plesiotype, 0.42 mm; breadth, 0.25 mm.

BOLIVINA HASTATA Phleger and Parker
Pl. VIII, fig. 12

1951. *Bolivina hastata* PHLEGER and PARKER, Geol. Soc. America, Mem. 46, pt. 2, p. 13, pl. 6, figs. 18a, b, 19.

This species closely resembles in many respects the larger *Bolivina fragilis,* and, like *B. fragilis,* it shows variation in the costae, most of the Pleistocene specimens being smooth. Nearly all specimens have an apical spine. Length of plesiotype, 0.32 mm; breadth, 0.13 mm.

BOLIVINA LOWMANI Phleger and Parker
Pl. VIII, fig. 5

1951. *Bolivina lowmani* PHLEGER and PARKER, Geol. Soc. America, Mem. 46, pt. 2, p. 13, pl. 6, figs. 20a, b, 21.

This species occurs in abundance in 6 feet of water at the present location of the South Pass Block 41 well. The species was also found in this boring at a depth of 4900 feet, near the top of the Pliocene, as well as in marine intervals throughout the Pleistocene. Length of plesiotype, 0.23 mm; breadth, 0.09 mm.

BOLIVINA MINIMA Phleger and Parker
Pl. VIII, fig. 11

1951. *Bolivina minima* PHLEGER and PARKER, Geol. Soc. America, Mem. 46, pt. 2, p. 14, pl. 6, figs. 22a, b, 25; pl. 7, figs. 1, 2.

This distinctive species is rare in the Gulf Coast Pleistocene. Fossil specimens are identical with the holotype and paratypes from the Gulf of Mexico. The species resembles *Bolivina catanensis* Seguenza from which it is easily distinguished by its serrate margin and more slender test. Length of homeotype, 0.29 mm; breadth, 0.14 mm.

BOLIVINA ORDINARIA Phleger and Parker
Pl. VIII, fig. 4

1951. *Bolivina simplex* PHLEGER and PARKER, (not *B. interjuncta* Cushman var. *simplex* Cushman and Renz, 1941), Geol. Soc. America, Mem. 46, pt. 2, p. 14, pl. 7, figs. 4-6.
1952. *Bolivina ordinaria* PHLEGER and PARKER, Contr. Cushman Found. Foram. Res., vol. 3, pt. 1, p. 14.

A few specimens are identical with the holotype and paratypes from the Gulf of Mexico. Length of plesiotype, 0.23 mm; breadth, 0.13 mm.

BOLIVINA PACIFICA Cushman and McCulloch
Pl. VIII, fig. 17

1942. *Bolivina acerosa* Cushman var. *pacifica* CUSHMAN and MCCULLOCH, Allan Hancock Pacific Exped., vol. 6, no. 4, p. 185, pl. 21, figs. 2-3.

Paratypes of *B. acerosa pacifica* borrowed from the U. S. National Museum show similarity to holotype of *B. acerosa* Cushman only in slenderness of test. Cushman's species is less compressed. The two foraminifers do not appear so closely related as indicated by Cushman and McCulloch. Pleistocene specimens of *B. pacifica* show varia-

tions in size and width of test but include the dimensions of primary types in the range of variation. Our specimens have distinct, clear areas at the upper and inner portion of each chamber as do specimens from the Pacific Recent described by the above authors. In this respect, *B. pacifica* resembles *B. translucens* Phleger and Parker and *B. daggarius* Parker. Length of plesiotype, 0.32 mm; breadth, 0.13 mm; thickness, 0.06 mm.

BOLIVINA PLICATELLA Cushman
Pl. VIII, fig. 16

1930. *Bolivina plicatella* CUSHMAN, Florida Geol. Survey, Bull. 4, p. 46, pl. 8, figs. 10a, b.

Small, infrequent specimens occur in the lower part of the Pleistocene section, particularly in the sidewall core at 3258 feet in the South Pass Block 41 well. These compare closely with topotypes from the type locality, cut in road leading to Watson's Landing, Apalachicola River, Liberty County, Florida. This species has also been reported from the Pliocene of N. Carolina, Florida, and Cuba, and from the Miocene of N. Carolina, Maryland, and the Buff Bay Formation in Jamaica. Cushman reported it in the Pleistocene of the Panama Canal zone and as living in the W. Indian region and southward. There is close similarity with *Bolivina pseudoplicata* Heron-Allen and Earland with which there may be an infraspecific relationship. Length of plesiotype, 0.19 mm; breadth, 0.16 mm.

BOLIVINA SPINATA Cushman
Pl. VIII, fig. 10

1936. *Bolivina striatula* Cushman var. *spinata* CUSHMAN, Cushman Lab. Foram. Res., Spec. Publ. 6, p. 59, pl. 8, figs. 9a, b.

Typical specimens were found only in the uppermost beds of the Pleistocene. They were compared with the holotype from north of Puerto Rico. Length of plesiotype, 0.48 mm; breadth, 0.15 mm.

BOLIVINA cf. B. STRIATULA Cushman
Pl. VIII, fig. 9

1922. *Bolivina striatula* CUSHMAN, Carnegie Inst. Washington, Publ. 311, p. 27, pl. 3, fig. 10.

Due to the fragmental condition of the few small forms found, this reference is made with reservations. The two Pleistocene specimens from 578 feet in the South Pass Block 41 well are relatively wider than Recent specimens from the Gulf of Mexico. Length of figured specimen (incomplete test), 0.40 mm; breadth, 0.17 mm.

B. striatula has been reported from the Pleistocene of Florida, and from the Miocene of Jamaica and the Dominican Republic.

BOLIVINA SUBAENARIENSIS Cushman
Pl. VIII, figs. 20, 28

1899. *Bolivina aenariensis* FLINT (part, not Costa), Rept. U. S. Natl. Mus., (1897), pt. 2, p. 292, pl. 37, fig. 6.
1922. *Bolivina subaenariensis* CUSHMAN, U. S. Natl. Mus., Bull. 104, pt. 3, p. 46, pl. 7, fig. 6.

Typical specimens are abundant in a sidewall core at 3490 feet in the South Pass Block 41 well. The type of this species is from 250 fathoms southeast of Nantucket. Cushman records it in the reference above as common from south of Nova Scotia to Cape Hatteras. Our specimens were compared with the paratypes.

It is interesting that the typical form and the two foraminifers considered as subspecies, *Bolivina subaenariensis mexicana* Cushman and *B. subaenariensis lucida,* n. subsp., occur in the same sample (3490 feet). At 3540 feet in the same well, however, *B. subaenariensis* occurs frequently to the exclusion of both subspecies. The actual genetic relationship of these three sympatric forms is unknown. They may belong to distinct biologic species. Gradations cannot be discerned between these groups in our samples. Further data toward determining whether these forms are truly allopatric in modern seas as implied by Cushman in the above reference would be interesting. Length of plesiotypes, 0.53 mm, 0.50 mm; breadth, 0.23 mm, 0.21 mm; thickness, 0.11 mm, 0.09 mm.

BOLIVINA SUBAENARIENSIS LUCIDA
Akers and Dorman, new subspecies
Pl. VIII, figs. 2, 18, 25

1881-1882. *Bolivina aenariensis* H. B. BRADY (not Costa), Proc. Roy. Soc. Edinburgh, p. 711.
1884. *Bolivina aenariensis* H. B. BRADY, Rept. Voy. Challenger, Zool., vol. 9, p. 423, pl. 53, figs. 10, 11.
1937. *Bolivina subaenariensis* Cushman var. CUSHMAN, Cushman Lab. Foram. Res., Spec. Publ. 9, p. 156.
1953. *Bolivina subaenariensis* Cushman. DROOGER, Contr. Cushman Found. Foram. Res., vol. 4, pt. 4, p. 132, pl. 21, figs. 11-13.

Distinct differences are seen in this form from *Bolivina subaenariensis mexicana* Cushman. Our specimens probably belong to the same group as those mentioned by Cushman in the above reference from the Atlantic coasts of Europe. The subspecies differs from the typical in having higher, less oblique chambers and clear instead of opaque chambers. *B. subaenariensis lucida* differs from *B. subaenariensis mexicana* Cushman in having fewer costae and in that the costae do not extend so close to the apertural end of the test. In these respects our subspecies is closer to the typical than is *B. subaenariensis mexicana. B. subaenariensis lucida* differs from both the typical and *B. subaenariensis mexicana* in that the sutures are limbate with considerable increase in limbosity at the median line. Our subspecies has a short spine at the apical end as do the other forms. The test is thin and fragile. Of several hundred specimens examined not one was entire. Length of holotype (pl. VIII, fig. 25), 0.63 mm; width, 0.25 mm. Length of paratypes, 0.55 mm, 0.45 mm; width, 0.21 mm for both specimens.

Holotype and paratypes are from the core at 3300 feet in California Company State Lease 2553, well number 1, South Pass Block 41, Plaquemines Parish, Louisiana. Drooger's specimens from Aruba (see above reference) seem to belong to this group, but their age may be Pleistocene rather than Miocene.

BOLIVINA SUBAENARIENSIS MEXICANA Cushman

Pl. VIII, figs. 13, 19

1922. *Bolivina subaenariensis* Cushman var. *mexicana* CUSHMAN, U. S. Natl. Mus., Bull. 104, pt. 3, p. 47, pl. 8, fig. 1.

Bolivina subaenariensis mexicana and *B. lowmani* occur most frequently in the Gulf Coast Pleistocene of all representatives of this genus. Length of plesiotype, pl. VIII, fig. 19, 0.50 mm; breadth, 0.21 mm. Length of plesiotype, pl. VIII, fig. 13, 0.42 mm; breadth, 0.23 mm.

The holotype of this foraminifer is from the Gulf of Mexico. Miocene occurrences are reported for Jamaica and the Dominican Republic. The writers have it from the Louisiana subsurface Pliocene.

BOLIVINA SUBSPINESCENS Cushman

Pl. VIII, figs. 6, 15

1922. *Bolivina subspinescens* CUSHMAN, U. S. Natl. Mus., Bull. 104, pt. 3, p. 48, pl. 7, fig. 5.

Fossil specimens are typical of the species. Most records for this species in the Atlantic and Gulf of Mexico are deeper than 50 meters. It is reported from the Miocene of Egypt. Length of plesiotype (fig. 15), 0.29 mm; breadth, 0.15 mm.

Forms are common in the lower part of the Pleistocene, particularly in the core at 3258 feet in the South Pass Block 41 well, in which the basal portion of the chambers are only slightly granular. Although this results in a somewhat different appearance from the individuals with short spines, these forms are considered here as variants. This is done largely on the basis of variation noted by Cushman in the above reference. Length of figured variant (pl. VIII, fig. 6), 0.23 mm; breadth, 0.11 mm.

BOLIVINA cf. B. SUBTENUIS Cushman

Pl. VIII, fig. 35

1936. *Bolivina subtenuis* CUSHMAN, Cushman Lab. Foram. Res., Spec. Publ. 6, p. 57, pl. 8, fig. 10.

A single, broken specimen may belong to this group. Specimens from the Recent of Samoa are greatly compressed, and this is also a distinctive characteristic of our Pleistocene specimen. Apertural comparisons cannot be made, however, due to the damaged condition of our specimen. Length of figured specimen (incomplete), 0.42 mm; breadth, 0.29 mm; thickness, 0.12 mm.

BOLIVINA THALMANNI Renz

Pl. VIII, fig. 27

1948. *Bolivina thalmanni* RENZ, Geol. Soc. America, Mem. 32, p. 120.

A few specimens are referred to this species although they are not as close to the holotype as are Louisiana Gulf Coast Miocene specimens. Pleistocene individuals, particularly those from the Aftonian beds, approach the dimensions of the holotype from the Pozon Formation in northern Venezuela, but the characteristic ridges are less sharp than those in the Tertiary specimens from the Gulf Coast and Venezuela.

Some of our forms seem to be intermediate between *Bolivina plicatella* Cushman and *Bolivina thalmanni* Renz. *Bolivina plicatella* is smaller, and the longitudinal ridges are

less distinct than in the Pleistocene forms. Possibly these two species belong with *Bolivina pseudo-plicata* Heron-Allen and Earland in a group of *Bolivina*s probably of subgeneric rank in which the test is thick and the wall deeply reticulate. Length of plesiotype, 0.40 mm; breadth, 0.26 mm.

Bolivina translucens Phleger and Parker
Pl. VIII, fig. 33

1951. *Bolivina translucens* Phleger and Parker, Geol. Soc. America, Mem. 46, pt. 2, p. 15, pl. 7, figs. 13, 14a, b.

Only a few specimens were found; these seem to be identical with the holotype and paratypes from the Recent sediments of the Gulf of Mexico. Length of plesiotype, 0.21 mm; breadth, 0.08 mm.

Buccella hannai (Phleger and Parker)
Pl. X, figs. 3, 4

1951. *Eponides hannai* Phleger and Parker, Geol. Soc. America, Mem. 46, pt. 2, p. 21, pl. 10, figs. 11a, b, 12a, b, 13a, b, 14a, b.

In the South Pass Block 41 well, frequencies are low in beds below the Montgomery Formation. Diameter of plesiotype, 0.27 mm; thickness, 0.17 mm.

Buccella sp.
Pl. X, figs. 29, 30

Two specimens of a small, tightly coiled *Buccella* were found at 2418 feet in the South Pass Block 41 well. The form is distinctive from both *B. hannai* and *B. mansfieldi* in its tight coiling and relatively high spire. Additional specimens are needed for adequate description of the species. Diameter of figured specimen, 0.23 mm; thickness, 0.15 mm.

Bulimina aculeata d'Orbigny
Pl. VII, fig. 33

1826. *Bulimina aculeata* d'Orbigny, Ann. Sci. Nat., vol. 7, p. 269, no. 7.

Frequent in the South Pass Block 41 well at two horizons, 3490 and 3574 feet. The species is not common in other zones of the Pleistocene section. Phleger and Parker (1951, p. 44) record it as present in the Gulf of Mexico at depths usually greater than 500 meters. The shallowest record in the Atlantic is at 100 meters. This foraminifer is also recorded from the Miocene of Mallorca, Morocco, Jamaica (Cushman and Todd, 1945, p. 39), and the Dominican Republic (Bermudez, 1949, p. 179) and from the Pliocene and Miocene of Italy. Length of plesiotype, 0.40 mm; breadth, 0.28 mm.

Bulimina alazanensis spatiosa Cushman and Todd
Pl. VII, fig. 37

1945. *Bulmina alazanensis* Cushman var. *spatiosa* Cushman and Todd, Cushman Lab. Foram. Res., Spec. Publ. 15, Sharon, Mass., p. 40.

Specimens of Yarmouth age are identical with our topotypes from the Miocene locality 1/2 mile east of Buff Bay, Jamaica. The species is rare in the South Pass Block 41 well, but it is common at 1830 feet in California P.O.D. no. 7, South Pass Block 24 Field. Length of plesiotype, 0.82 mm; breadth, 0.46 mm.

Bulimina marginata d'Orbigny
Pl. VII, figs. 14, 39

1826. *Bulimina marginata* d'Orbigny, Ann. Sci. Nat., vol. 7, p. 269, no. 4, pl. 12, figs. 10-12.

Pleistocene specimens, like Recent forms from the Gulf of Mexico, are variable. Two variants are figured. Length of plesiotype, pl. VII, fig. 14, 0.38 mm; breadth, 0.23 mm. Length of plesiotype, pl. VII, fig. 39, 0.42 mm; breadth, 0.32 mm.

The species has been identified from several Caribbean localities of Miocene age and from the Miocene of Louisiana and Florida. In Italy the range is Upper Miocene to Recent.

Bulimina patagonica d'Orbigny
Pl. VII, fig. 38

1839. *Bulimina patagonica* d'Orbigny, Voy. Amér. Mérid., vol. 5, pt. 5, "Foraminifères", Strasbourg, France, Levrault, p. 50.

Specimens were compared with the holotype of *Bulimina patagonica* d'Orbigny var. *glabra* Cushman and Wickenden from off Chile. Some of our forms are entirely smooth, and they are identical with the variety in size and other aspects, but others have short spines at the bases of the chambers. Our specimens are referred to the species instead of the variety, therefore, on this evidence that the ornamentation is variable. We have also seen this species in Recent samples off the coast of Louisiana. Length of plesiotype, 0.27 mm; breadth, 0.15 mm.

BULIMINA SPICATA Phleger and Parker
Pl. VII, fig. 22

1951. *Bulimina spicata* Phleger and Parker, Geol. Soc. America, Mem. 46, pt. 2, p. 16, pl. 7, figs. 25a-c, 30, 31.

Pleistocene specimens were compared with the holotype and paratype from Recent sediments in the Gulf of Mexico. Phleger and Parker (1951, p. 44) record the species in the Gulf of Mexico at depths greater than about 100 meters. Parker (1954, pp. 510-511) records it deeper than 70 meters in the northeastern Gulf of Mexico. Length of plesiotype, 0.21 mm; breadth, 0.13 mm.

BULIMINA STRIATA MEXICANA Cushman
Pl. VII, fig. 15

1922. *Bulimina striata* d'Orbigny var. *mexicana* CUSHMAN, U. S. Natl. Mus., Bull. 104, pt. 3, p. 95, pl. 21, fig. 2.

Comparisons were made with the holotype and paratypes from the Atlantic Ocean. The species is common in the Gulf of Mexico, especially below about 200 meters (Phleger and Parker, 1951, p. 44). It also occurs in middle latitudes of the Atlantic from 80 meters to 2430 meters. Our Pleistocene specimens also seem to be identical with individuals from the Miocene locality 1/2 mile east of Buff Bay, Jamaica. Length of plesiotype, 0.38 mm; breadth, 0.32 mm.

BULIMINELLA cf. B. BASSENDORFENSIS Cushman and Parker
Pl. VII, figs. 4-7

1937. *Buliminella bassendorfensis* CUSHMAN and PARKER, Contr. Cushman Lab. Foram. Res., vol. 13, pt. 1, p. 40, pl. 4, figs. 13a, b.

Small specimens are identical with Recent specimens from the Gulf of Mexico which have been referred questionably to this species (Phleger and Parker, 1957, p. 17; Parker, 1954, p. 509). Variants occur at 3520 feet in the South Pass Block 41 well which are approximately twice as large as Recent individuals from the Gulf of Mexico. Most of these tend to be subfusiform, and all specimens at this horizon show a well-developed basal spine. One individual has two small basal spines. Andersen (1961, p. 87) may be correct in referring this form to a new species, *Buliminella morgani* Andersen, although specimens from the Pleistocene and the Gulf of Mexico Recent are similar to the types of *B. bassendorfensis* from the Oregon Oligocene. Length of figured specimen, pl. VII, fig. 7, 0.27 mm; breadth, 0.08 mm. Length of specimen, pl. VII, fig. 4, 0.46 mm; breadth, 0.17 mm. Length of specimen, pl. VII, fig. 5, 0.36 mm; breadth, 0.16 mm. Length of specimen, pl. VII, fig. 6, 0.36 mm; breadth, 0.18 mm.

BULIMINELLA ELEGANTISSIMA (d'Orbigny)
Pl. VII, fig. 36

1839. *Bulimina elegantissima* D'ORBIGNY, Voy. Amér. Mérid., vol. 5, pt. 5, "Foraminifères", p. 51, pl. 7, figs. 13, 14.

B. elegantissima was described from off the west coast of South America. It is found in the Gulf of Mexico from beach sands to 385 meters (Phleger and Parker, 1951, p. 17) and from 15 meters to 90 meters off Maryland (Parker, 1948, p. 222). The senior writer has found it to be most frequent off the coast of Louisiana at depths less than 50 meters. This species has been reported from the Pliocene-Pleistocene and the Miocene of the Dominican Republic. It is also reported from Pliocene to Recent of Cuba and from the Miocene of Florida. Only a few very small specimens were found. Length of plesiotype, 0.15 mm; breadth, 0.07 mm.

CANCRIS SAGRA (d'Orbigny)
Pl. XI, figs. 24, 25

1839. *Rotalina sagra* D'ORBIGNY *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères", p. 77, pl. 5, figs. 13-15.

A subdivision of Recent and Pleistocene *Cancris* does not seem practical with present data. It seems advisable, therefore, to refer all our specimens to the above species, although some variation may be observed in length of test, curvature of sutures, nature of periphery, and other features. Length of plesiotype, 0.46 mm; breadth, 0.33 mm; thickness, 0.17 mm.

This species group is widely reported from the Recent of the Atlantic, Caribbean, and Gulf of Mexico and from the Miocene of the Caribbean and the Gulf Coast. It is almost worldwide in distribution both in Recent seas and in Tertiary sediments.

CASSIDULINA CURVATA Phleger and Parker
Pl. XI, fig. 5

1951. *Cassidulina curvata* PHLEGER and PARKER, Geol. Soc. America, Mem. 46, pt. 2, p. 26, pl. 14, figs. 5a, b.

Fossil specimens were compared with the holotype from the Gulf of Mexico. Diameter of plesiotype, 0.23 mm.

CASSIDULINA LAEVIGATA d'Orbigny
Pl. XI, fig. 4

1826. *Cassidulina laevigata* D'ORBIGNY, Ann. Sci. Nat., vol. 7, p. 282, no. 1, pl. 15, figs. 4, 5; Modèles, no. 41.

Our specimens are typical of some of the forms assigned to this species. Diameter of plesiotype, 0.25 mm.

The species is recorded from the Pliocene of North Carolina, the Oligocene of Puerto Rico, and the Miocene of coastal Louisiana, Jamaica, the Dominican Republic, Italy, and Morocco. It is also reported from the Tertiary of Colombia, Venezuela, Barbados, Trinidad, Mexico, and California and from the Plio-Pleistocene of the Netherlands.

CASSIDULINA NEOCARINATA Thalmann
Pl. XI, fig. 1

1896. *Cassidulina laevigata* d'Orbigny var. *carinata* SILVESTRI, Accad. Pont. N. Lincei, Mem. 12, p. 104, pl. 2, fig. 10.

1950. *Cassidulina neocarinata* THALMANN, Contr. Cushman Found. Foram. Res., vol. 1, pts. 3 and 4, p. 44.

The species is reported in Italy from Middle Miocene to Recent. Our Pleistocene specimens were compared with Pliocene specimens from the vicinity of Siena, Italy. This foraminifer is also recorded from the Florida Miocene. Gulf Coast individuals seem to lie within the range of variation of the species. Diameter of plesiotype, 0.27 mm.

This form is listed in figures 2 and 3 as *Cassidulina carinata* Silvestri.

CASSIDULINA NORCROSSI AUSTRALIS Phleger and Parker
Pl. XI, fig. 6

1951. *Cassidulina norcrossi australis* PHLEGER and PARKER, Geol. Soc. America, Mem. 46, pt. 2, p. 27, pl. 14, figs. 8a, b, 9, 10.

Pleistocene fossil specimens are identical with Recent individuals from the Gulf of Mexico. Diameter of plesiotype, 0.22 mm.

CHRYSALIDINELLA sp.
Pl. IX, fig. 20

A single specimen was found which is not referred to a species. Length of figured specimen, 0.32 mm; breadth, 0.13 mm.

CIBICIDES aff. C. FLORIDANUS (Cushman)
Pl. XV, figs. 26, 27

1918. *Truncatulina floridana* CUSHMAN, U. S. Geol. Surv., Bull. 676, p. 62, pl. 19, fig. 2.

Several variable groups of specimens are referred to this species. It has been noted (Phleger and Parker, 1951, p. 30) that the larger, more limbate Recent forms in the Gulf of Mexico generally occur in the samples from deeper water. This may also have been the case with the Pleistocene forms. The largest of our specimens, which have a diameter of 0.95 mm, occur within the interval 3104 to 3590 feet in the South Pass Block 41 well. Maximum diameter of figured specimen, 0.74 mm; thickness, 0.39 mm.

CIBICIDES NUCLEATUS (Seguenza)
Pl. XV, figs. 21-23

1880. *Truncatulina nucleata* SEGUENZA, Atti R. Accad. Lincei III, vol. 6, p. 64, pl. 7, fig. 8.

1928. *Truncatulina trinitatensis* NUTTALL, Quart. Journ. Geol. Soc. London, vol. 84, p. 97, pl. 7, figs. 3, 5, 6.

1929. *Cibicides nucleata* (Seguenza). GALLOWAY and MORREY, Bull. Amer. Paleontology, vol. 15 (55), p. 31, pl. 4, fig. 9.

1932. *Cibicides trinitatensis* (Nuttall). NUTTALL, Journ. Paleontology, vol. 6, p. 33, pl. 7, fig. 9.

1934. *Cibicides trinitatensis* (Nuttall). HADLEY, Bull. Amer. Paleontology, vol. 20 (70A), p. 29, pl. 4, figs. 10, 11.

1940. *Anomalina nucleata* (Seguenza). CORYELL and RIVERO, Journ. Paleontology, vol. 14, p. 334, pl. 44, figs. 2a-c.

1941. *Anomalina nucleata* (Seguenza). GALLOWAY and HEMINWAY, New York Acad. Sci., Sci. Survey Porto Rico and Virgin Is., vol. 3, pt. 4, p. 388, pl. 22, fig. 2.

1941. *Cibicides nucleatus* (Seguenza). D. K. PALMER, Mem. Soc. Cubana Hist. Nat., vol. 15, p. 296.

1945. *Cibicides nucleatus* (Seguenza). D. K. PALMER, Bull. Amer. Paleontology, vol. 29, no. 115, p. 73.

1948. *Anomalinoides trinitatensis* (Nuttall). RENZ, Geol. Soc. America, Mem. 32, p. 115, pl. X, figs. 11a-c.

1949. *Cibicides nucleatus* (Seguenza). BERMUDEZ, Cushman Lab. Foram. Res., Spec. Pub. 25, 303, pl. 24, figs. 16-18.

1951. *Cibicides robustus* PHLEGER and PARKER, (not Le Calvez, 1949), Geol. Soc. America, Mem. 46, pt. 2, p. 31, pl. 17, figs. 1a, b, 2a, b, 3a, b, 4a, b.

1952. *Cibicides corpulentus* PHLEGER and PARKER, Contr. Cushman Found. Foram. Res., vol. 3, pt. 1, p. 14.
1954. *Cibicides corpulentus* Phleger and Parker. PARKER, Harvard, Bull. Mus. Comp. Zoology, vol. 111, no. 10, p. 541, pl. 12, figs. 4, 8.

Galloway and Heminway point out in the reference above on Puerto Rican Tertiary Foraminifera "considerable variation in sutural limbation and thickness of the umbos in this species (or these species), depending more on the ontogenetic age of the specimens than on the geologic age". Phleger and Parker separate Gulf of Mexico specimens from *C. nucleatus* on the basis of the "much larger plug on dorsal side—and much more limbate sutures".

The writers have compared specimens from the Gulf of Mexico, including holotype and paratypes of *C. corpulentus* Phleger and Parker, with specimens from the Miocene Carapita of Venezuela, the Miocene of Trinidad, the Miocene of Jamaica, the Middle Tertiary of Mexico, the subsurface Miocene of Louisiana, and the Miocene of the Balearic Islands. The range of variation in all of these regions and also in the Gulf Coast Pleistocene is similar. Limbate specimens with large umbos from the Gulf of Mexico, for example, cannot be differentiated from limbate specimens with large umbos from the Carapita of Venezuela.

Other occurrences of this group have been reported from the Middle Tertiary of Ecuador, Cuba, Haiti, Barbados, and Carriacou. *C. nucleatus* was described from the Miocene of Italy. Phleger and Parker found this form limited to water deeper than about 120 meters in the Gulf of Mexico. All of the fossil assemblages containing this species which were examined by the present writers are suggestive of a depositional environment of several hundred meters water depth.

Maximum diameter of plesiotype, 0.74 mm; thickness, 0.38 mm.

CIBICIDES aff. C. PROTUBERANS Parker
Pl. XV, figs. 11, 12

1954. *Cibicides protuberans* PARKER, Harvard, Bull. Mus. Comp. Zoology, vol. 111, no. 10, p. 542, pl. 12, figs. 13, 14, 16.

A few specimens are assigned tentatively to this species although most are smaller than indicated in the above reference for Recent Gulf of Mexico forms. Maximum diameter of figured specimens, 0.34 mm; thickness, 0.13 mm.

The holotype, which was borrowed for purposes of comparison, shows later and wider whorls than do our specimens. Pleistocene individuals appear indistinguishable from the young stages of the Recent specimens, however.

CIBICIDES aff. C. ROBERTSONIANUS (H. B. Brady)
Pl. XV, figs. 24, 25

1881. *Truncatulina robertsoniana* H. B. BRADY, Quart. Journ. Micr. Sci., vol. 21, p. 65.
1884. *Truncatulina robertsoniana* H. B. BRADY, Rept. Voy. Challenger, Zool., vol. 9, p. 664, pl. 95, figs. 4a-c.

A variable group of small specimens is referred tentatively to this species. Maximum diameter of figured specimen, 0.21 mm; thickness, 0.11 mm.

CIBICIDES UMBONATUS Phleger and Parker
Pl. XV, figs. 7, 8

1951. *Cibicides umbonatus* PHLEGER and PARKER, Geol. Soc. America, Mem. 46, pt. 2, p. 31, pl. 17, figs. 7a, b, 8a, b.

Pleistocene specimens were compared with the holotype and paratypes from the Gulf of Mexico, and they seem to be typical in all respects. According to Phleger (1951, p. 45) the species is not recorded in the Gulf of Mexico shallower than 100 meters. Maximum diameter of plesiotype, 0.48 mm; thickness, 0.21 mm.

This species appears to be closely related to *Eponides crebbsi* Hedberg from the Middle Tertiary of Venezuela differing mainly in the character of the sutures on the umbilical side.

CIBICIDES WUELLERSTORFI (Schwager)
Pl. XV, figs. 16, 17

1866. *Anomalina wuellerstorfi* SCHWAGER, Novara-Exped., Geol. Theil., vol. 2, p. 258, pl. 7, figs. 105, 107.

The species ranges in Italy throughout the post-Eocene Cenozoic. There seems to be confusion in the literature between *Planulina ariminensis* d'Orbigny (Recent (?), near Rimini, Italy) and this species. Study of the problem may indicate that *C. wuellerstorfi* is a junior synonym of *P. ariminensis.*

Our specimens are close to those from the Gulf of Mexico which have been referred to *C. wuellerstorfi.* Phleger (1951, p. 48) records it from Gulf of Mexico stations deeper

than 700 meters. In the Atlantic, it is reported from 630 meters to 4450 meters. The species occurs in that part of the Gulf Coast Pleistocene which has been inferred to represent deep water deposition (Akers and Holck, 1957, pl. 1). The species was described from the Miocene of Kar Nikobar. As *"Planulina wuellerstorfi,"* it is also reported from the Middle Tertiary of Trinidad, Colombia, and the Dominican Republic; and it is found in the Louisiana Miocene. Maximum diameter of plesiotype, 0.55 mm; thickness, 0.13 mm.

This form is listed in figures 2 and 3 as *Planulina wuellerstorfi* (Schwager).

CYCLAMMINA CANCELLATA H. B. Brady
Pl. I, fig. 1

1876. *Cyclammina cancellata* H. B. BRADY (MS.) *in* NORMAN, Proc. Roy. Soc., vol. 25, p. 214;
1884. *Cyclammina cancellata* H. B. BRADY, Rept. Voy. Challenger, Zool., vol. 9, p. 351, pl. 37, figs. 8-16.

A single but typical specimen was found at 1875 feet in the South Pass Block 24 well. The depth range in the Gulf of Mexico recorded for Recent specimens is 366 to 2660 meters. Temperature extremes of 1.9 and 6.72 degrees centigrade have been reported (Akers, 1954, p. 138). The species is widespread in modern seas and Middle Tertiary deposits. Maximum diameter of plesiotype, 2.04 mm; thickness, 0.48 mm.

CYCLOGYRA PLANORBIS (Schultze)
Pl. IV, fig. 5

1854. *Cornuspira planorbis* SCHULTZE, Organismus Polythal, p. 40, pl. 2, fig. 21.

Only a few small specimens were found. As in Recent deposits in the Gulf of Mexico, according to Phleger and Parker (1951, p. 8), the species is characteristic of calcareous sediments. Diameter of plesiotype, 0.19 mm; thickness, 0.06 mm.

DENTALINA COMMUNIS d'Orbigny
Pl. VI, fig. 12

1826. *Nodosaria (Dentalina) communis* D'ORBIGNY, Ann. Sci. Nat., vol. 7, p. 254, no. 25.

A few specimens seem to be referable to this group. Miocene occurrences are reported for Florida, Jamaica, Mallorca, and Morocco. In Cuba, the range is from Upper Eocene to Recent. Length of plesiotype, 0.46 mm; breadth, 0.13 mm.

DENTALINA cf. D. DISPAR Reuss
Pl. V, fig. 32

1851. *Dentalina dispar* REUSS, Zeitschr. deutsch. geol. Ges., vol. 3, p. 61, pl. 3, fig. 7.

A single small specimen is tentatively referred here. The species is reported from the Tertiary of Europe and from Buff Bay, Jamaica. Length of figured specimen, 0.22 mm; breadth, 0.04 mm.

DENTALINA VERTEBRALIS ALBATROSSI (Cushman)
Pl. V, fig. 33

1923. *Nodosaria vertebralis* var. *albatrossi* CUSHMAN, U. S. Natl. Mus., Bull. 104, pt. 4, p. 87, pl. 15, fig. 1.

Usually only broken specimens of this large foraminifer are found. Fossil specimens are identical with Recent individuals from the Gulf of Mexico. The subspecies is reported from the Miocene Buff Bay locality of Jamaica and from the Miocene of Mallorca. Length of plesiotype, 4.35 mm; breadth of final chamber, 0.45 mm.

ELPHIDIUM DISCOIDALE (d'Orbigny)
Pl. VII, figs. 16, 17

1839. *Polystomella discoidalis* D'ORBIGNY *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères", p. 56, pl. 6, figs. 23, 24.

This is probably the most frequently encountered species of the genus in the Gulf Coast Pleistocene. Specimens seem to be largest in calcareous zones. Bermudez (1949, p. 168) records the species from the Tertiary of the Dominican Republic. Forms reported by Drooger (1953) from Aruba may be of Pleistocene or Pliocene age rather than Miocene as he supposed. Maximum diameter of plesiotype, 0.59 mm; thickness, 0.32 mm.

ELPHIDIUM FIMBRIATULUM (Cushman)
Pl. VII, figs. 28, 29

1918. *Polystomella fimbriatulum* CUSHMAN, U. S. Geol. Survey, Bull. 676, p. 20, pl. 8, figs. 5a, b.

Specimens are usually rare and small. They cannot be differentiated from forms which occur in the Miocene Chipola and Hawthorn Facies of the Alum Bluff Stage in Florida. The species is also reported from the Pliocene and Oligocene (?) of Cuba and from the Miocene of Jamaica and the Dominican Republic. It was described from the Pliocene of Florida. A related form with

17 chambers instead of 12 is reported from the Gulf of Mexico (Phleger and Parker, 1951, p. 10). Maximum diameter of plesiotype, 0.50 mm; thickness, 0.23 mm.

ELPHIDIUM POEYANUM (d'Orbigny)
Pl. VII, figs. 31, 32

1839. *Polystomella poeyana* D'ORBIGNY *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères", p. 55, pl. 6, figs. 25, 26.

Pleistocene specimens are typical of the species which was described from the Recent of the Caribbean. It is also reported from the Pliocene of Cuba and from the Pliocene and Pleistocene of Florida. Miocene occurrences are recorded for Florida, Jamaica, Colombia, Puerto Rico, Cuba, Venezuela, and the Dominican Republic. Maximum diameter of plesiotype, 0.63 mm; thickness, 0.17 mm.

ELPHIDIUM SAGRUM (d'Orbigny)
Pl. VII, figs. 26, 27

1839. *Polystomella sagra* D'ORBIGNY *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères", p. 55, pl. 6, figs. 19, 20.

This species is most frequently encountered in calcareous zones. It is recorded from both Recent and Tertiary of the Caribbean region and from the Anahuac Formation of Texas and Louisiana. In Cuba it is reported from Upper Oligocene (?) to Recent, and it occurs in the Pliocene and Pleistocene of Florida. Maximum diameter of plesiotype, 0.58 mm; thickness, 0.34 mm.

ELPHIDIUM sp. indeterminate

Specimens with the greatest diameter less than 0.40 mm were not speciated because specific assignment of juveniles is often difficult to determine. Specimens belonging to the genus *Elphidium* may be diagnostic of certain environments, particularly by weight of numbers. For this purpose, forms with a diameter less than 0.40 mm are included in the frequency charts as *Elphidium* sp. indeterminate.

EPISTOMINELLA VITREA Parker
Pl. XI, figs. 7, 8

1953. *Epistominella vitrea* PARKER *in* PARKER, PHLEGER and PEIRSON, Cushman Found. Foram. Res., Spec. Publ. 2, p. 9, pl. 4, figs. 34-36, 40, 41.

Fossil specimens are similar to Recent individuals from the Gulf of Mexico. The same form occurs in the Louisiana Pliocene. Immature individuals resemble *Epistominella exigua* (H. B. Brady). Specimens from 3430 feet in the South Pass Block 41 well may belong to *E. exigua,* but this cannot be established with certainty because of their immaturity. Diameter of plesiotype, 0.19 mm; thickness, 0.08 mm.

EPONIDELLA GARDENISLANDENSIS Akers
Pl. X, figs. 26, 27

1952. *Eponidella gardenislandensis* AKERS, Journ. Paleontology, vol. 26, no. 4, p. 648, figs. 2a, b, c.

Fossil specimens are typical of those found in modern brackish-water bays of South Louisiana. This species is often associated both in Recent and Pleistocene sediments with the reworked tests of *Chiloguembelina.* Diameter of heautotype, 0.15 mm; thickness, 0.06 mm.

FISSURINA sp. "A"
Pl. VII, figs. 19, 20

A single small specimen at 578 feet in the South Pass Block 41 well is not referred to a species because of its small size. Length of figured specimen, 0.15 mm; breadth, 0.11 mm; thickness, 0.08 mm.

FISSURINA sp. "B"
Pl. VII, fig. 10

A single specimen at 3560 feet in the South Pass Block 41 well is distinctive, but additional specimens are not readily available for proper description of the species. Length of figured specimen, 0.27 mm; breadth, 0.19 mm; thickness, 0.13 mm.

FISSURINA sp. "C"
Pl. VII, figs. 8, 9

The illustrated specimen is typical of a species which is rather frequent at 1830 feet in The California Company, P.O.D. #7, South Pass Block 24. Because of confusion in the literature relating to this genus, identification with a described species is deferred. It resembles *Lagena marginata* Walker and Boys as figured by Flint (1899, p. 307, pl. 54, fig. 2) from the Recent of the Caribbean, Gulf of Mexico, and South Atlantic. Length of figured specimen, 0.32 mm; breadth, 0.25 mm; thickness, 0.17 mm.

FISSURINA sp. "D"
Pl. VII, figs. 11, 12

Our specimens seem to belong to the same species as that misidentified by Flint

(1899, p. 307, pl 54, fig. 1) as *Lagena staphyllearia* Schwager from the Caribbean in 896 fathoms. Our species is closer to *Fissurina dominicana* (Bermudez) from the Tertiary of the Dominican Republic. Length of figured specimen, 0.39 mm; breadth, 0.32 mm; thickness, 0.21 mm.

FLORILUS ATLANTICUS (Cushman)
Pl. VI, figs. 26, 27

1947. *Nonionella atlantica* CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 23, pt. 4, p. 90, pl. 20, figs. 4, 5.
1954. *Nonionella atlantica* Cushman. PARKER, Harvard, Bull. Mus. Comp. Zool., vol. 111, no. 10, p. 507, pl. 6, figs. 6, 7.

Our specimens are typical of the Atlantic and Gulf of Mexico forms. The species was described from off the Atlantic coast of Florida. Length of plesiotype, 0.48 mm; breadth, 0.34 mm; thickness, 0.23 mm. The species is reported from the Miocene of Colombia and the Calabrian (Lower Pleistocene) of Italy.

This species is listed in figures 2 and 3 as *Nonionella atlantica* Cushman.

FLORILUS GRATELOUPI (d'Orbigny)
Pl. VI, fig. 36

1826. *Nonionina grateloupi* D'ORBIGNY, Ann. Sci. Nat., vol. 7, p. 294, no. 19.
1839. *Nonionina grateloupi* D'ORBIGNY *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères", p. 46, pl. 6, figs. 6, 7.

This species, described from the Recent of the West Indies, is present in the Pleistocene in low frequencies. It is reported from the Pleistocene, Pliocene, and Miocene of Florida and from the Tertiary of Cuba, Jamaica, Colombia, the Dominican Republic, and France. Length of plesiotype, 0.59 mm; breadth, 0.38 mm; thickness, 0.21 mm.

This form is listed in figures 2 and 3 as *Nonion grateloupi* (d'Orbigny).

FRONDICULARIA SAGITTULA Vanden Broeck
Pl. VI, figs. 31-33

1876. *Frondicularia alata* d'Orbigny var. *sagittula* VANDEN BROECK, Ann. Soc. Belge Micr., vol. 2, p. 113, pl. 2, figs. 12, 14.

Specimens over 5 mm in length occur in the Upper Pleistocene of the Louisiana Gulf Coast. Although a wide range of variation is shown, they seem to be conspecific with Recent and Miocene specimens from the Caribbean region. Length of plesiotype (incomplete specimen), pl. VI, fig. 31, 2.18 mm; breadth, 1.66 mm. Length of plesiotype (incomplete specimen), pl. VI, fig. 33, 5.46 mm; breadth, 2.98 mm. Length of plesiotype (incomplete specimen), pl. VI, fig. 32, 4.20 mm; breadth, 2.42 mm.

FURSENKOINA cf. F. BRADYI (Cushman)
Pl. VII, fig. 21

1884. *Virgulina subsquammosa* H. B. BRADY (part, not Egger), Rept. Voy. Challenger, Zool., vol. 9, p. 415, pl. 52, figs. 9a-c (7, 8?).
1922. *Virgulina bradyi* CUSHMAN, U. S. Natl. Mus., Bull. 104, pt. 3, p. 115, pl. 24, fig. 1.

We have only a single specimen which is tentatively referred to *F. bradyi*. Length of figured specimen, 0.44 mm; diameter, 0.17 mm.

FURSENKOINA COMPLANATA (Egger)
Pl. VIII, fig. 31

1893. *Virgulina schreibersiana* Czjzek var. *complanata* EGGER, Abhandl. k. bay. Akad. Wiss. München, vol. 18, pt. 2, p. 292, pl. 8, figs. 91, 92.

This small, slender species is common throughout the marine Pleistocene, and it has been recorded from the Buff Bay Miocene of Jamaica. The species has not been found in our samples from Buff Bay, however. The types are from off Western Australia in 90 to 359 meters. *F. complanata* has been found in the Gulf of Mexico in all depths of water. It is most widespread in depths less than 1000 meters according to Phleger (1951, p. 49). The range in Italy is Tortonian to Quaternary. Length of plesiotype, 0.29 mm; diameter, 0.11 mm.

FURSENKOINA FINISSIMA Akers and Dorman, n. sp.
Pl. VIII, figs. 29, 30

Test very small, elongate, slender, only slightly compressed, translucent; chambers low for the genus; sutures narrow, depressed, oblique, slightly curved; wall smooth, finely perforate; aperture elongate, broad. Length of holotype, 0.25 mm; maximum breadth, 0.05 mm. Holotype from core at 1270 feet in California Company State Lse. 2553, well number 1, South Pass Block 41, Plaquemines Parish, Louisiana.

This species is similar to *F. complanata* Egger, especially in size, but does not develop the abrupt expansion in the later portion of the test commonly seen in that species. The chambers are shorter, and the

aperture is not so broad and conspicuous as in *F. complanata.*

FURSENKOINA MEXICANA (Cushman)
Pl. VII, fig. 35

1922. *Virgulina mexicana* Cushman, U. S. Natl. Mus., Bull. 104, pt. 3, p. 120, pl. 23, fig. 8.

Compressed specimens from the Pleistocene belong to this species group. The types are from the Gulf of Mexico in 347 fathoms. Length of plesiotype, 0.49 mm; breadth, 0.21 mm; thickness, 0.10 mm.

FURSENKOINA PONTONI (Cushman)
Pl. VIII, fig. 32

1932. *Virgulina pontoni* CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 8, pt. 1, p. 17, pl. 3, fig. 7.

There is confusion in the literature between this species and *F. schreibersiana* (Czjzek). We have compared *F. pontoni* from the Florida Miocene with *F. schreibersiana* from Miocene beds in the vicinity of Baden, Austria, and also from the Pliocene of Italy. Some of our Pleistocene specimens and specimens from the Florida Miocene are more compressed than the European species. These we believe should be assigned to *F. pontoni,* although in our samples it would not be unreasonable to consider *F. pontoni* as a variant of *F. schreibersiana. F. pontoni* has been recorded from Tertiary beds of Venezuela, Colombia, Trinidad, Jamaica, and California, as well as from the Miocene of Florida and Louisiana. Phleger and Parker (1951, p. 19) have identified the species from the Gulf of Mexico. Length of plesiotype, 0.67 mm; breadth, 0.24 mm; thickness, 0.15 mm.

FURSENKOINA SCHREIBERSIANA (Czjzek)
Pl. VII, fig. 34

1848. *Virgulina schreibersiana* CZJZEK, Haidinger's Nat. Abhandl., vol. 2, p. 11, pl. 13, figs. 18-21.

Some of the Pleistocene specimens are very similar to topotypes in our collection from the vicinity of Baden, Austria. See discussion under *F. pontoni* (Cushman). The species has been identified from the Miocene of California, tentatively (Cushman and Todd, 1945, p. 42) from the Miocene of Jamaica and tentatively from the Middle Tertiary of the Gulf Coast. It has been recorded in Europe from beds of Oligocene to Pliocene age and from stations off the Philippines and southward to Fiji. It is reported from the Weddell Sea by Earland. The range in Italy is Upper Oligocene to Quaternary. Length of plesiotype, 0.82 mm; diameter, 0.20 mm.

GAUDRYINA AEQUA Cushman
Pl. I, fig. 19

1947. *Gaudryina aequa* CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 23, pt. 4, p. 87, pl. 18, figs. 18-21.

Fossil specimens seem to belong to the same species as that described by Cushman in the above reference from off the southeastern coast of the U. S. They are identical with specimens from the Gulf of Mexico tentatively referred to this species by Phleger and Parker (1951) and Parker (1954). Length of plesiotype, 0.42 mm; breadth, 0.25 mm.

GAUDRYINA (PSEUDOGAUDRYINA) ATLANTICA (Bailey)
Pl. I, fig. 23

1851. *Textularia atlantica* BAILEY, Smithsonian Contr. Knowl., vol. 2, art. 3, p. 12, pl., figs. 38-43.

This species is present in several zones of the Gulf Coast Pleistocene. Recent specimens have been reported in the Gulf of Mexico with a depth range of 90 meters to 300 meters. Fossil specimens are reported from the Miocene of Cuba, Jamaica, the Dominican Republic, and Aruba (possibly Pleistocene). Length of plesiotype, 2.00 mm; breadth, 1.11 m.

GLOBOBULIMINA AFFINIS (d'Orbigny)
Pl. VII, fig. 13

1839. *Bulimina affinis* D'ORBIGNY *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères", p. 105, pl. 2, figs. 25, 26.
1945. *Bulimina (Desinobulimina) illingi* CUSHMAN and STAINFORTH, Cushman Lab. Foram. Res., Spec. Publ. 14, p. 41, pl. 6, fig. 7.
1954. *Globobulimina affinis* (d'Orbigny). PARKER, Harvard, Bull. Mus. Comp. Zoology, vol. 111, no. 10, pl. 6, fig. 25; pl. 7, figs. 1, 2.

Pleistocene specimens compare closely with Parker's hypotypes from the Gulf of Mexico. The species is also recorded from the Middle Tertiary of Mallorca, Haiti, Cuba, and the Dominican Republic and from Middle Miocene to Recent in Italy. Length of plesiotype, 0.40 mm; breadth, 0.27 mm.

GLOBOBULIMINA MISSISSIPPIENSIS Parker
Pl. VII, fig. 3

1954. *Globobulimina mississippiensis* PARKER, Harvard, Bull. Mus. Comp. Zoology, vol. 111, no. 10, pl. 7, figs. 3, 4, 10.

Identification of our fossil specimens was verified by comparison with the holotype and paratypes from the Gulf of Mexico. Length of plesiotype, 0.44 mm; breadth, 0.29 mm.

GLOBULINA CARIBAEA d'Orbigny
Pl. VI, fig. 30

1839. *Globulina caribaea* D'ORBIGNY *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères", p. 135, pl. 2, figs. 7, 8.
1954. *Globulina caribaea* d'Orbigny. PARKER, Harvard, Bull. Mus. Comp. Zoology, vol. 111, no. 10, p. 506, pl. 5, fig. 23.

A few Pleistocene specimens were found which are typical of forms from the Gulf of Mexico assigned to this species by Parker in the above reference. Length of plesiotype, 0.42 mm; diameter, 0.36 mm.

GLOBULINA sp.
Pl. VI, fig. 23

Slightly elongate specimens were found which are not assigned to a species. These are rare, and they may have variable characteristics. Length of figured specimen, 0.40 mm; diameter, 0.25 mm.

GUTTULINA AUSTRALIS (d'Orbigny)
Pl. VI, fig. 28

1839. *Globulina australis* D'ORBIGNY, Voy. Amer. Mérid., vol. 5, pt. 5, "Foraminifères", p. 60, pl. 1, figs. 1-4.
1870. *Polymorphina regina* BRADY, PARKER and JONES, Linnaean Soc. London Trans., vol. 27, p. 241, pl. 41, figs. 32a, b.

Pleistocene specimens are typical of Recent forms from the Gulf of Mexico which have been referred to this species. This species group has variable characteristics among which are thickness of the test, length, and height of costae. Length of plesiotype, 0.57 mm; breadth, 0.27 mm.

This foraminifer is recorded from the Miocene of Maryland and South Carolina (Cushman, 1918, p. 54).

GUTTULINA PULCHELLA d'Orbigny
Pl. VI, fig. 29

1839. *Guttulina pulchella* D'ORBIGNY *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères", A. Bertrand, Paris, France, p. 134.

Specimens are rare. The figured specimen is typical of the species. Length of plesiotype, 0.65 mm; breadth, 0.21 mm.

This species has been reported from the Pliocene of Florida (Cole, 1931, p. 29), but there do not seem to be any records for it in the Miocene.

GUTTULINA sp.
Pl. VI, fig. 13

A few small specimens are not referred to a species. Length of figured specimen, 0.36 mm; breadth, 0.23 mm.

GYPSINA VESICULARIS (Parker and Jones)
Pl. XV, fig. 18

1860. *Orbitolina vesicularis* PARKER and JONES, Ann. Mag. Nat. Hist., ser. 3, vol. 6, p. 31, no. 5.

Specimens typical of Recent forms from the Gulf of Mexico were found to be frequent in the calcareous zone, 578 to 610 feet, in the South Pass Block 41 well. Diameter of plesiotype, 0.69 mm; thickness, 0.47 mm.

The species has been reported from the Middle Tertiary of Venezuela and Trinidad and from the Miocene of Louisiana.

GYROIDINOIDES NEOSOLDANII (Brotzen)
Pl. X, figs. 20, 21

1884. *Rotalia soldanii* H. B. BRADY, (not *Gyroidina soldanii* d'Orbigny, 1826), Rept. Voy. Challenger, Zool., vol. 9, p. 706, pl. 107, figs. 6, 7.
1936. *Gyroidina neosoldanii* BROTZEN, Sver. Geol. Unders., ser. C, no. 396, p. 158.

This species is reported from the South Pacific and North Pacific Oceans and from the Gulf of Mexico. Our small Pleistocene specimens are similar to Recent specimens from the Gulf of Mexico. The species has also been recorded in Italy from Middle Miocene to Recent.

This form is listed in figures 2 and 3 as *Gyroidina neosoldanii* Brotzen.

GYROIDINOIDES ORBICULARIS (d'Orbigny)
Pl. X, figs. 31, 32

1826. *Gyroidina orbicularis* D'ORBIGNY, Ann. Sci. Nat., ser. 1, vol. 7, p. 278; Modèles, no. 13.

Pleistocene specimens are typical of Recent forms from the Gulf of Mexico which

Parker (1954, p. 528) has assigned to *Gyroidina orbicularis* d'Orbigny. Phleger (1951, p. 47) reports this species as most prevalent in the Gulf of Mexico between 500 and 1000 meters but extending from 135 to 1600 meters. Bagg (1898, p. 38) records this foraminifer from the Miocene of Virginia. Diameter of plesiotype, 0.46 mm; height, 0.29 mm.

This form is listed in figures 2 and 3 as *Gyroidina orbicularis* d'Orbigny.

GYROIDINOIDES REGULARIS (Phleger and Parker)
Pl. X, figs. 7, 8

1951. *Eponides regularis* PHLEGER and PARKER, Geol. Soc. America, Mem. 46, pt. 2, p. 21, pl. 11, figs. 3a, b, 4a-c.
1953. *Gyroidina venezuelana* (Renz) var. *arubana* DROOGER, Contr. Cushman Found. Foram. Research, vol. 4, pt. 4, p. 138, pl. 22, figs. 5, 6.

Fossil specimens are typical of Recent specimens assigned to *Eponides regularis* Phleger and Parker. Phleger (1951, p. 46) records the species in the Gulf of Mexico between 150 meters and about 1000 meters. This foraminifer is closely related to *Gyroidinoides scalata* (Garrett) from the Oligocene and Miocene of Louisiana. The Quaternary form has 8 to 9 chambers in the final whorl. The Tertiary form, *G. scalata,* has 12 to 13 chambers in the final whorl. Size, shape of test, and umbilicus are similar in the two species. Both are related to *Gyroidinoides planulata* (Cushman and Renz) from the Middle Tertiary of Venezuela, Trinidad, Ecuador, Barbados, and the Dominican Republic. *G. planulata* and *Gyroidina laevis* Coryell and Rivero from the Tertiary of Haiti probably should be considered synonyms of *Gyroidinoides scalata. G. regularis* is distinctive, however, in having fewer chambers. Diameter of plesiotype, 0.19 mm; height, 0.08 mm.

GYROIDINOIDES SOLDANII ALTIFORMIS (R. E. and K. C. Stewart)
Pl. X, figs. 33-35

1930. *Gyroidina soldanii* d'Orbigny var. *altiformis* R. E. and K. C. STEWART, Journ. Paleontology, vol. 4, no. 3, p. 67, pl. 9, fig. 2.

Specimens are most frequent in the lower part of the marine Pleistocene. These are typical of Recent specimens from the Gulf of Mexico. Phleger (1951, p. 47) reports this form as common down to 1850 meters and not recorded shallower than 200 meters. Natland (1933) records the species from the San Pedro Channel of Southern California between 274 and 2542 meters at temperatures of 3° to 8.5°C. Originally described from the Lower Pliocene of California, the form has been reported from the Middle Tertiary of Venezuela, Trinidad, Jamaica, the Dominican Republic, Cuba, and Mexico. It also occurs in the Miocene of Louisiana. Diameter of plesiotype, 0.61 mm; height, 0.53 mm.

HANZAWAIA CONCENTRICA (Cushman)
Pl. XV, figs. 3, 4

1918. *Truncatulina concentrica* CUSHMAN, U. S. Geol. Surv., Bull. 676, p. 64, pl. 21, fig. 3.

See discussion under *H. strattoni* for differentiation between these two species. Figs. 3, 4, pl. XV, illustrate a specimen arbitrarily assigned to *H. concentrica* but closely related to *H. strattoni.* Diameter of plesiotype, 0.65 mm; thickness, 0.24 mm.

Specimens referred to this species have been reported from the Pleistocene and Pliocene of Cuba and from the Middle Tertiary of Florida, Louisiana, Cuba, Jamaica, Barbados, Haiti, Venezuela, and the Dominican Republic. In the Gulf of Mexico, *H. concentrica* is a shallow water species. According to Phleger (1951, p. 45), the greatest abundance is in depths less than 100 meters.

HANZAWAIA cf. H. CONCENTRICA (Cushman)
Pl. XV, figs. 1, 2

A few specimens were found at 2418 feet in the South Pass Block 41 well which probably constitute a distinct species. These are referred tentatively to *H. concentrica* in the absence of sufficient material for the recognition of persistent features. A well-developed and somewhat unique keel is characteristic of this form. Punctae are rather coarse. Diameter of figured specimen, 0.42 mm; thickness, 0.16 mm.

HANZAWAIA STRATTONI (Applin)
Pl. XV, figs. 13, 14

1925. *Truncatulina americana* Cushman var. *strattoni* APPLIN *in* APPLIN, ELLISOR and KNIKER, Bull. Amer. Petr. Geol., vol. 9, no. 1, p. 99, pl. 3, fig. 3.

Representatives of this species group are variable in limbation of sutures, number of chambers in the final whorl, and height of

chambers. A gradation seems to exist between this species and *Hanzawaia concentrica* (Cushman). We have referred all specimens which are biconvex to *H. strattoni.* Specimens with one side slightly to definitely flattened and with a keel or even the suggestion of a keel are referred to *H. concentrica.* In some cases separation is arbitrary. Comparison of assemblages would be necessary to determine whether some of the specimens from the Middle Tertiary of the Caribbean-West Indian region identified as *H. concentrica* would be referable to *H. strattoni* using the above criteria. The holotype is from the subsurface Miocene of Louisiana. Diameter of plesiotype, 0.53 mm; thickness, 0.21 mm.

HAUERINA NACCHARA Akers and Dorman, n. sp.
Pl. III, figs. 1-6

Test strongly compressed except for early quinqueloculine portion; later portion planispiral with two chambers to the coil; peripheral margin subacute, slightly crenulate in adult forms; wall of adult forms bearing oblique, raised, rounded ridges and depressions; usually white in color with nacreous luster; aperture cribrate.

Diameter of holotype (pl. III, figs. 1-3), 0.44 mm by 0.36 mm. Diameter of paratype (pl. III, figs. 4-6), 0.42 mm by 0.32 mm. Thickness of both specimens, 0.09 mm. Holotype and paratype from core at 610 feet in the California Company, State Lease 2553, well number 1, South Pass Block 41 field.

This form seems to be distinct from previously described species. It resembles *Hauerina speciosa* (Karrer) but is less compressed than figured specimens of that species. Our species does not have the transverse striations on the radial ridges so prominent in *H. ornatissima* (Karrer), and the keel is more rounded than in that species.

HOEGLUNDINA ELEGANS (d'Orbigny)
Pl. XI, figs. 30, 31

1826. *Rotalia (Turbulina) elegans* D'ORBIGNY, Ann. Sci. Nat., vol. 7, p. 276, no. 54.

Pleistocene specimens are typical of the species. Recent specimens are recorded in the Gulf of Mexico by Parker (1954, p. 531) deeper than 65 meters. Phleger (1951, p. 47) records it between 90 meters and 3550 meters in the Gulf of Mexico. Miocene specimens have been reported from both the Caribbean and the Mediterranean regions. Diameter of plesiotype, 0.55 mm; thickness, 0.30 mm. In Cuba the range has been recorded as Upper Eocene to Recent and in Italy, Upper Oligocene to Recent.

HYALINEA BALTHICA (Schroeter)
Pl. X, figs. 18, 19

1783. *Nautilus balthicus* SCHROETER, Einleitung, vol. 1, p. 20, pl. 1, fig. 2.
1884. *Operculina ammonoides* Parker and Jones (not Gronovius). H. B. BRADY, Rept. Voy. Challenger, Zoology, vol. 9, p. 745, pl. 92, figs. 1, 2.
1931. *Anomalina balthica* (Schroeter). CUSHMAN, U. S. Natl. Mus., Bull. 104, pt. 8, pp. 108-109, pl. 19, figs. 3a-c.
1951. *Hyalinea balthica* (Schroeter). HOFKER, Foraminifera of the Siboga Exped., pt. 3, pp. 508-513, figs. 345-348.
1952. *Hofkerinella balthica* (Schroeter). BERMUDEZ, Boletin de Geologia, vol. 2, no. 4, pp. 74-75.
1953. *Anomalina balthica* (Schroeter). PHLEGER, PARKER, and PEIRSON, Repts. Swed. Deep-sea Exped., 1947-1948, vol. 7, fasc. 1, p. 48, pl. 10, figs. 24, 25.

In the South Pass Block 41 well, megalospheric and microspheric specimens occur in abundance between 3258 and 3912 feet. Two megalospheric specimens were found in the core at 9440 feet in association with *Globigerina inflata* and *G. bulloides.* Five specimens, all megalospheric, were identified as part of a sparse fauna in the core at 9990 feet. Previous usage is followed in this assignment although it should be pointed out that the specific identification might be questioned owing to the great discrepancy in the number of chambers in the last formed whorl of the form figured by Schroeter from the Baltic Sea. His figure shows 24 chambers in the final whorl, while specimens from various North Atlantic localities, fossil and Recent individuals from the Mediterranean region, and our Pleistocene specimens do not have more than 11 or 12. The figures by Brady, Cushman, and Phleger, Parker, and Peirson appear identical and are clearly representative of specimens from the Louisiana Pleistocene. Immersion of our specimens in glycerin clearly revealed the simple umbilical canal system described by Hofker in the above reference.

This is one of the few reported occurrences from the western side of the Atlantic. Cushman (1931, p. 109) states that the species is very abundant in the cold waters of the North Atlantic, especially on the eastern side. Colom (1950) records it as frequent to abundant in his deepest facies, 300-878 meters off the west coast of Africa. Hofker's specimens are from the vicinity of Sumatra in 340 and 377 fathoms. *Hyalinea balthica* has been found in the deep, cool waters of the Mediterranean, and in Italy the marine Pleistocene (Calabrian) is recognized and differentiated from marine Pliocene on the lowermost occurrence of this foraminifer and other cool water species (Alliata, 1946, 1947; Coggi and Alliata, 1950; Ilacqua, 1956). Thus the known stratigraphic range of the species in the Mediterranean region and also the Atlantic is Lower Pleistocene (Calabrian) to Recent. To date, sampling in the Gulf of Mexico has failed to disclose *H. balthica* in Recent sediments. It has been found at eighteen stations in the eastern Mediterranean from 106 to 799 meters (Parker, 1958, p. 275).

None of the Gulf Coast Pleistocene specimens exceeds 0.40 mm in diameter. Maximum diameter of microspheric plesiotype, (pl. X, fig. 18), 0.40 mm; thickness, 0.08 mm. Maximum diameter of megalospheric plesiotype (pl. X, fig. 19), 0.29 mm; thickness, 0.08 mm.

ISLANDIELLA CRASSA (d'Orbigny)
Pl. XI, figs. 16-18

1839. *Cassidulina crassa* D'ORBIGNY, Voy. Amér. Mérid., vol. 5, pt. 5, "Foraminifères", p. 56, pl. 7, figs. 18-20.

We are following current interpretations of d'Orbigny's species in this assignment. Forms assigned to this species both in Recent sediments and in Pleistocene beds show variation. There may be several subspecies or even several species grouped here. *I. crassa* has been reported from the Miocene of Florida and the Cojimar (Oligocene?) Formation of Cuba. The reported range in Italy is Upper Miocene to Recent. Maximum diameter of plesiotype, 0.34 mm; thickness, 0.21 mm.

This species is listed as *Cassidulina crassa* d'Orbigny in figures 2 and 3.

ISLANDIELLA SUBGLOBOSA (H. B. Brady)
Pl. XI, fig. 19

1881. *Cassidulina subglobosa* H. B. BRADY, Quart. Journ. Micr. Sci., vol. 21, p. 30 (60);
1884. *Cassidulina subglobosa* H. B. BRADY, Rept. Voy. Challenger, Zool., vol. 9, p. 430, pl. 54, figs. 17a-c.

Several variants are assigned to this species. Pleistocene variation is similar to that described by Parker (1954, p. 536) for Recent specimens in the northeastern Gulf of Mexico. As in Recent assemblages, the variants appear to merge into one another, and it is not practical to differentiate them. The largest and apparently typical form occurs in relatively high frequency at 3560 feet in the South Pass Block 41 well. This is the form which Parker found limited to deep water in the Gulf of Mexico. Maximum diameter of plesiotype, 0.40 mm.

The species group has been reported from the Tertiary of Cuba, Venezuela, Jamaica, Trinidad, the Dominican Republic, and Morocco. It has been identified throughout the post-Paleocene Cenozoic of Italy.

This species is listed as *Cassidulina subglobosa* H. B. Brady in figures 2 and 3.

LAGENA GRACILLIMA (Seguenza)
Pl. VI, fig. 17

1862. *Amphorina gracillima* Seguenza, Dei terreni Terziarii del distretto di Messina; Parte II—Descrizione dei foraminiferi monotalamici delle marne mioceniche del distrettodi Messina. Messina, Italia, T. Capra, p. 51, pl. 1, fig. 37.

Fragile, broken specimens are recognizable as lying within the range of variation of this species. According to Cushman, however, concerning numerous records in Recent waters, "there seems to be a question as to whether this is really a very widely distributed species or whether, being of a smooth type with very few distinguishing characters, there may be several forms included under this name" (1923, p. 24). The form has been recorded from the Pliocene and Miocene of Italy. Length of plesiotype, 0.32 mm; breadth, 0.11 mm.

LAGENA GRACILLIMA MOLLIS Cushman
Pl. VI, fig. 10

1944. *Lagena gracillima* (Seguenza) var. *mollis* CUSHMAN, Contr. Cushman Lab. Foram. Res., Spec. Publ. 12, p. 21, pl. 3, fig. 3.

Although they are usually fragmental, it is possible to refer a few specimens to this

subspecies. The type is from the Recent of Casco Bay, Maine. Length of plesiotype (broken), 0.29 mm; breadth, 0.08 mm.

LAGENA cf. L. HISPIDA Reuss
Pl. VI, fig. 9

1863. *Lagena hispida* REUSS, K. Akad. Wiss. Wien, Math.-Naturw. Cl., Sitzber., Wien, Osterreich, Bd. 46, Abth. 1, p. 335, pl. 6, figs. 77-79.

A few specimens were found which may belong here. Length of figured specimen, 0.21 mm.

LAGENA STRIATA (d'Orbigny)
Pl. VI, fig. 11

1839. *Oolina striata* D'ORBIGNY, Voy. Amér. Mérid., vol. 5, pt. 5, "Foraminifères", p. 21, pl. 5, fig. 12.

Pleistocene specimens are typical of this species. Miocene specimens are reported from Mallorca, Morocco, Jamaica and the Dominican Republic. The species is also reported from the *Heterostegina* Zone of the Gulf Coast Middle Tertiary (Applin, Kniker, and Ellisor, 1925). In Italy, the form is recorded throughout the post-Eocene Cenozoic. Length of plesiotype, 0.29 mm.

LAGENA SULCATA SPICATA Cushman and McCulloch
Pl. VI, fig. 24

1950. *Lagena sulcata* (Walker and Jacob) var. *spicata* CUSHMAN and MCCULLOCH, Southern California, Univ., Publ., Allan Hancock Pacific Exped., vol. 6, no. 6, p. 360, pl. 48, figs. 3-7.

Pleistocene specimens lie within the range of variation of this widely distributed Pacific species. *Lagena sulcata* (Walker and Jacob) was described from off the coast of England and has been reported from the Middle Tertiary of Texas, Florida, and the Dominican Republic. *L. sulcata spicata* was described from the Pacific Ocean. It is not known whether this form also occurs in Tertiary sediments. Length of plesiotype, 0.21 mm.

LAGENA sp. A

A single smooth form was found, and speciation is deferred pending additional specimens necessary for determination of specific characteristics.

LAGENA sp. B

A single specimen having short spines arranged in longitudinal rows was found. The form is spicate, but our specimen is preserved with only a trace of this feature.

LENTICULINA cf. L. ARCUATO-STRIATA (Hantken)
Pl. IV, figs. 9, 10

1868. *Cristellaria (Robulina) arcuato-striata* HANTKEN, Magyar. Földt. Társ., Munk., Pest. Magyarország, vol. 4, p. 93, pl. 2, fig. 30.

Our Pleistocene specimens may be related to this Oligocene species from Hungary. Comparison should be made with the holotype or topotypes, however, before a definite identification is accepted. The species is also reported from the Middle Tertiary of Cuba and the Dominican Republic. Diameter of figured specimen, 0.69 mm; thickness, 0.41 mm.

LENTICULINA ATLANTICA (Barker)
Pl. IV, figs. 13, 14

1923. *Cristellaria lucida* CUSHMAN, U. S. Natl. Mus., Bull. 104, pt. 4, p. 111, pl. 30, fig. 2.
1960. *Robulus atlanticus* BARKER, S.E.P.M. Spec. Publ. no. 9, p. 144, pl. 69, figs. 10-12.

The species was described from the Recent of the Atlantic Ocean. Occurrences are recorded from the Miocene of Jamaica and the Dominican Republic. Maximum diameter of plesiotype, 0.84 mm; thickness, 0.38 mm.

This form is listed in figures 2 and 3 as *Lenticulina lucida* (Cushman).

LENTICULINA BOWDENENSIS (Cushman)
Pl. IV, figs. 22-26

1919. *Cristellaria bowdenensis* CUSHMAN, Carnegie Inst. Wash., no. 291, p. 37, pl. 8, fig. 2.
1923. *Cristellaria antillea* CUSHMAN, U. S. Natl. Mus., Bull. 104, pt. 4, p. 116, pl. 31, fig. 1; pl. 32, fig. 1; pl. 33, fig. 1; pl. 34, fig. 1.

Large, compressed specimens are abundant in the upper portion of the Gulf Coast Pleistocene. The species is highly variable in the development of the keel and peripheral spines, thickness of the test, development of beads on the sutures, and beading of the test wall between sutures. The species is recorded from the Miocene of Jamaica and the Dominican Republic as well as from Recent stations listed in the reference above.

Dimensions of plesiotypes are as follows: pl. IV, fig, 24, maximum diameter (including spines), 2.65 mm, thickness, 0.80 mm; pl. IV, fig. 25, 2.21 mm, 0.61 mm; pl. IV, fig. 26, 1.70 mm, 0.44 mm; pl. IV, figs. 22 and 23, 1.64 mm; 0.50 mm.

LENTICULINA CALCAR (Linné)
Pl. IV, fig. 8

1758. *Nautilus calcar* LINNÉ, Syst. Nat., ed. 10, p. 709.
1923. *Cristellaria calcar* (Linné). CUSHMAN, U. S. Natl. Mus., Bull. 104, pt. 4, p. 115, pl. 30, fig. 7; pl. 31, figs. 4, 5.

Pleistocene specimens are identical with Recent specimens from the Gulf of Mexico. This widely reported Recent species is also recorded from numerous Middle Tertiary areas including localities in Ecuador, Colombia, Venezuela, Trinidad, Jamaica, Barbados, Cuba, Haiti, Mexico, Louisiana, California, the Dominican Republic, Mallorca, and Italy. In Italy it ranges from Middle Miocene to Quaternary. Diameter of plesiotype (including spines), 0.47 mm; thickness, 0.24 mm.

LENTICULINA CULTRATA (Montfort)
Pl. IV, fig. 21

1808. *Robulus cultratus* MONTFORT, Conchyliologie systematique et classification methodique des coquilles, Paris, France, F. Schoell, tome 1, p. 215.
1923. *Cristellaria iota* CUSHMAN, U. S. Natl. Mus., Bull. 104, part 4, p. 111, pl. 29, fig. 2; pl. 30, fig. 1.

Our specimens were compared with the holotype of Cushman from the Gulf of Mexico. These are identical, but both probably should be referred to Montfort's species from the Pliocene of Coroncina, Italy. Specimens in our collection from the Pliocene of Piacenza belong to this species group. The species is reported to range throughout the Italian Tertiary (Foraminiferi Padani, AGIP Mineraria, 1957). As *Robulus iotus,* this form is also recorded from the Middle Tertiary of Florida, Texas, Puerto Rico, Jamaica, Venezuela, the Dominican Republic, and Mallorca. As *R. cultratus,* it is reported from the Miocene and Oligocene of Cuba (Bermudez, 1950, p. 358). Maximum diameter of plesiotype (including keel), 2.08 mm; thickness, 0.82 mm.

LENTICULINA MELVILLI (Cushman and Renz)
Pl. IV, figs. 15, 16

1941. *Robulus melvilli* CUSHMAN and RENZ, Contr. Cushman Lab. Foram. Res., vol. 17, p. 12, pl. 2, fig. 12.

Specimens from the lower portion of the Pleistocene seem to be very close to this Miocene species from Venezuela. Middle Tertiary occurrences are also reported in the Dominican Republic and Jamaica. Maximum diameter of plesiotype, 0.66 mm; thickness, 0.38 mm.

LENTICULINA OCCIDENTALIS (Cushman)
Pl. IV, figs. 17, 18

1923. *Cristellaria occidentalis* CUSHMAN, U. S. Natl. Mus., Bull. 104, part 4, p. 102, pl. 25, fig. 2; pl. 26, figs. 1, 2.

Our specimens are similar to the holotype of Cushman from 1658 fathoms off the Northeastern Coast of the U. S. A variety, *Robulus occidentalis* var. *torridus* (Cushman), is recorded from several Caribbean Miocene and Oligocene localities. Maximum diameter of plesiotype, 0.71 mm; thickness, 0.40 mm.

LENTICULINA ORBICULARIS (d'Orbigny)
Pl. IV, figs. 19, 20

1826. *Robulina orbicularis* D'ORBIGNY, Ann. Sci. Nat., vol. 7, p. 288, pl. 15, figs. 8, 9.
1884. *Cristellaria orbicularis* (d'Orbigny). H. B. BRADY, Rept. Voy. Challenger, Zool., vol. 9, p. 549, pl. 69, fig. 17.
1899. *Cristellaria orbicularis* (d'Orbigny). FLINT, Rept. U. S. Natl. Museum, (1897), pt. 2, p. 317, pl. 64, fig. 3.
1923. *Cristellaria orbicularis* (d'Orbigny). CUSHMAN, U. S. Natl. Mus., Bull. 104, pt. 4, p. 101, pl. 21, fig. 7.

Our specimens are referred to this group as were others from the Atlantic Ocean and the Gulf of Mexico by previous authors, although it is likely that all of these are different from d'Orbigny's species from the Tertiary of Italy. The species has been reported from the Middle Tertiary of the Gulf Coast (Applin, 1926), the Dominican Republic, Morocco, and from the post-Paleocene Cenozoic of Italy. Diameter of plesiotype, 0.69 mm; thickness, 0.42 mm.

LENTICULINA PEREGRINA (Schwager)
Pl. V, figs. 8, 9

1866. *Cristellaria peregrina* SCHWAGER, Novara Exped., Geol. Theil., vol. 2, p. 245, pl. 7, fig. 89.

Typical specimens occur in the Gulf Coast Pleistocene. The illustrated specimen, how-

ever, is thicker than the typical. The species has wide distribution down to 1000 meters in the Gulf of Mexico but is not found shallower than about 45 meters (Phleger, 1951, p. 47). The known depth range in the North Atlantic is from 90 to 3350 meters. This species has also been recorded in Recent material from the Mediterranean, West Indies, and Pacific. The holotype is from the Middle Tertiary of Kar Nikobar. Middle Tertiary occurrences are reported from Japan, Haiti, and Jamaica. It is recorded from the Middle and Upper Miocene and Lower Pliocene of Italy. Length of plesiotype, 0.28 mm; breadth, 0.21 mm; thickness, 0.15 mm.

LENTICULINA ROTULATA (Lamarck)
Pl. V, figs. 24, 25

1806. *Lenticulites rotulata* LAMARCK, Ann. Mus., vol. 8, p. 188, pl. 62, fig. 11.
1923. *Cristellaria rotulata* (Lamarck) ? CUSHMAN, U. S. Natl. Mus., Bull. 104, part 4, p. 108, pl. 22, fig. 2; pl. 28, figs. 1, 2.

Our specimens fit the description by Cushman in the above reference for Recent specimens from the Gulf of Mexico, Caribbean Sea, and Atlantic Ocean. The large umbo is distinctive in this species group. The species was described from probable Tertiary of France. Tertiary occurrences are also on record from Morocco, Panama, Jamaica, and the Dominican Republic. It is recorded throughout the post-Oligocene Cenozoic of Italy and from the *Marginulina* Zone of the Gulf Coast (Applin, Kniker, and Ellisor, 1925, p. 105). Maximum diameter of plesiotype, 0.86 mm; thickness, 0.53 mm.

LENTICULINA sp. "A"
Pl. V, figs. 3, 4

A few specimens of a "beaded" *Lenticulina* from low in the Pleistocene are similar to *Lenticulina senni* but lack the tendency to uncoil so pronounced in that species. Length of figured specimen, 0.97 mm; thickness, 0.55 mm.

LENTICULINA sp. "B"
Pl. V, figs. 1, 2

Insufficient specimens were found for an understanding of the range of variation of this form. Maximum diameter of figured specimen, 0.71 mm; thickness, 0.44 mm.

LENTICULINA sp. "C"
Pl. V. fig. 26

A few, large, compressed specimens were found in the uppermost Pleistocene beds which may be variants of *Lenticulina bowdenensis*. The periphery is distinctive in its marked lobulation. Length of figured specimen (broken), 3.34 mm; thickness, 0.63 mm.

LIEBUSELLA SOLDANII (Jones and Parker)
Pl. II, figs. 5, 6

1860. *Lituola soldanii* JONES and PARKER, Quart. Journ. Geol. Soc., vol. 16, p. 307, no. 184.

This species is widespread in the Middle Tertiary of the Caribbean region. It is also reported in Recent sediments of that region but seems to have been unreported in the Gulf Coast until now. Length of plesiotype, pl. II, fig. 5, 2.81 mm; breadth, 1.05 mm. Length of plesiotype, pl. II, fig. 6, 1.83 mm; breadth, 0.99 mm.

LINGULINA sp.
Pl. VI, figs. 5, 6

A single immature specimen showing similarity to *L. costata* d'Orbigny var. *seminuda* Hantken and *L. tricrenata* Coryell and Rivero was found in the highly fossiliferous core at 3300′ in the South Pass Block 41 well. Length of figured specimen, 0.50 mm; breadth, 0.49 mm; thickness, 0.38 mm.

MARGINULINA BASISPINOSA Cushman and Renz
Pl. V, figs. 11, 12

1941. *Marginulina basispinosa* CUSHMAN and RENZ, Contr. Cushman Lab. Foram. Res., vol. 17, p. 13, pl. 2, figs. 16-18.

Most of our specimens do not have peripheral spines or the costae typical of some of the specimens referred to this species in the above reference. The Pleistocene specimens, however, fall within the range of variation described for this species. A few specimens show short spines. Most are smooth and have limbate sutures. The species is recorded from the Tertiary of Venezuela, Colombia, and Trinidad. Length of plesiotype, pl. V, fig. 11, 1.37 mm; breadth, 0.46 mm; thickness, 0.42 mm. Length of plesiotype, pl. V, fig. 12, 1.07 mm; breadth, 0.48 mm; thickness, 0.40 mm.

MARGINULINA cf. M. COSTATA COARCTATA
Silvestri
Pl. V, figs. 14, 15

A single but well-preserved specimen from a core at 1885 feet in The California Company State Lease 1923, well no. 1, Dixon Bay Field, is tentatively assigned to this species from the Pliocene of Italy. The sutures are less distinct, and the test is considerably less compressed than in *M. planata.* Several specimens were found in Helvetian (of Colom, 1958) sediments from the Balearic Islands which seem to be identical with our Pleistocene form. Length of figured specimen, 1.68 mm; breadth, 0.48 mm; thickness, 0.44 mm.

MARGINULINA GLABRA d'Orbigny
Pl. V, fig. 10

1826. *Marginulina glabra* D'ORBIGNY, Ann. Sci. Nat., vol. 7, p. 259, no. 6.
1923. *Marginulina glabra* d'Orbigny. CUSHMAN, U. S. Natl. Mus., Bull. 104, pt. 4, p. 127, pl. 36, figs. 5, 6.

Two specimens were found at 545 feet in the South Pass Block 41 well. These are 0.36 mm in length as compared with d'Orbigny's measurements, "up to 2.0 mm in length." In other aspects, our specimens are typical of the species, which was described from Tertiary beds near Sienna, Italy. Occurrences in the Florida Miocene and a possible occurrence in the Miocene of Jamaica are reported. A variety, *M. glabra obesa,* is recorded from the Middle Tertiary of Venezuela. In Italy the range of the species is Middle Miocene to Quaternary. Le Calvez (1956, p. 591) records it from the Pliocene of Corsica.

MARGINULINA SUBACULEATA GLABRATA
(Cushman)
Pl. V, figs. 16-23

1923. *Cristellaria subaculeata* Cushman var. *glabrata* CUSHMAN, U. S. Natl. Mus., Bull. 104, pt. 4, p. 124, pl. 32, fig. 4; pl. 33, fig. 3; pl. 34, figs. 2, 3.
1951. *Marginulina subaculeata* (Cushman) var. *glabrata* (Cushman). PHLEGER and PARKER, Geol. Soc. America, Mem. 46, pt. 2, p. 9, pl. 5, fig. 4.

Pleistocene specimens are similar to Recent forms from the Gulf of Mexico including homeotypes of Phleger and Parker in above references. Peripheral spines are weakly developed in our specimens. Insufficient data are available for our proper evaluation of the infraspecific position that has been assigned in the above references to this highly variable form.

The following dimensions are recorded for plesiotypes: pl. V, figs. 19 and 20, length 1.43 mm, maximum breadth of *uncoiled portion* 0.74 mm, thickness 0.59 mm; pl. V, figs. 16 and 17, 1.13 mm, 0.53 mm, 0.44 mm; pl. V, figs. 22 and 23, 1.55 mm, 0.58 mm, 0.46 mm; pl. V, figs. 18 and 21, 1.60 mm, 0.55 mm, 0.42 mm.

Cushman (1923, p. 124) records the species from 309 to 384 meters in the Gulf of Mexico. It is reported from the Miocene of Colombia by Redmond (1953, p. 714), the Miocene of Jamaica by Cushman and Todd (1945, p. 18), and the Upper Oligocene (?) of Cuba by Bermudez, 1950, p. 348).

MARGINULINA SUBLITUUS MULTICAMERATA
Cushman and Stainforth
Pl. V, fig. 13

1945. *Marginulina sublituus* (Nuttall) var. *multicamerata* CUSHMAN and STAINFORTH, Cushman Lab. Foram. Res., Spec. Publ. 14, p. 23, pl. 3, figs. 6, 7.

Our figured specimen was compared with specimens from the Miocene Buff Bay locality of Jamaica. We have insufficient data to evaluate the infraspecific position of this form. It is possible that both Pleistocene specimens and specimens from the Cipero of Trinidad should be referred to the species of Nuttall from Mexico, although the type figure for this species illustrates a more compressed form. Length of plesiotype (fragmental), 0.48 mm; breadth, 0.19 mm; thickness, 0.15 mm.

MARGINULINOPSIS MARGINULINOIDES
(Goës)
Pl. V, fig. 27

1896. *Cristellaria aculeata* d'Orbigny var. *marginulinoides* GOES, Harvard, Bull. Mus. Comp. Zool., vol. 29, p. 56, pl. 5, figs. 15-16.

Our specimens are referred here, although not all have the peripheral spines described for the species. This seems to be a highly variable feature in this genus along with the width of the test and surface ornamentation. Phleger and Parker (1951, p. 9) record the species from the Gulf of Mexico and off Georgia from 125 meters to 180 meters. Length of plesiotype, 0.97 mm; maximum breadth of uniserial portion, 0.41 mm; thickness, 0.37 mm.

This form is listed in figures 2 and 3 as *Marginulina marginulinoides* (Goës).

Marginulinopsis senni lacrimata Akers and Dorman, n. subsp.
Pl. IV, figs. 6, 7

Presence in the Gulf Coast Lower Pleistocene of a foraminifer similar to the Miocene guide fossil of Venezuela, *Robulus senni* Cushman and Renz, is here noted. Our Quaternary form is thicker than the types of *Lenticulina senni,* and beads on the uncoiled portion of the test are elongated, tear shaped, in contrast with the beads shown by the species of Cushman and Renz which tend to become noticeably elongated only on the final chamber. Chambers are wider in the Venezuelan form, resulting in a test of greater proportional diameter than that shown by *M. senni lacrimata.* Length of holotype of the subspecies, 1.07 mm; thickness, 0.46 mm.

This form is listed in figure 3 as *Lenticulina senni lacrimata.*

Massilina sp.
Pl. II, figs. 14, 15

Only a few specimens of this distinctive form have been found. It is large, compressed, and has a capillate surface. Length of figured specimen, 1.32 mm; breadth, 1.10 mm.

Melonis pompilioides (Fichtel and Moll)
Pl. VI, fig. 16

1798. *Nautilus pompilioides* Fichtel and Moll, Testacea microscopica, p. 31.
1851. *Nonionina affinis* Reuss, Deutsch. Geol. Ges., Zeitschr., vol. 3, p. 72, pl. 5, fig. 32.
1958. *Nonion affine* (Reuss). Boltovskoy, Micropaleontology, vol. 4, no. 2, pp. 193-200.

This species was described from the Oligocene of Germany. Boltovskoy gives an excellent synonymy in the reference above and calls attention to the nomenclatorial confusion attendant upon this foraminifer.

The species has been reported under various synonyms from Eocene to Recent. It is recorded from Europe, North America, South America, the Caribbean region, and Fiji. It has been found in Recent samples from the North Atlantic, North Pacific, Red Sea, and the Gulf of Mexico and ranges throughout the post-Middle Oligocene Cenozoic of Italy. Parker (1954, p. 506) reports the species in the Gulf of Mexico from 60 meters to 1750 meters. Maximum diameter of plesiotype, 0.21 mm; thickness, 0.08 mm.

This form is listed in figures 2 and 3 as *Melonis affine.*

Neocuneolina angusta (Cushman)
Pl. I, figs. 24, 25

1919. *Cuneolina pavonia* d'Orbigny var. *angusta* Cushman, Carnegie Instit. Washington, Publ. 291, p. 34, pl. 7, fig. 2.
1963. *Neocuneolina angusta* (Cushman). Bermudez and Rivero, Estudio sistematico de los Foraminiferos Quitinosos, Microgranulares y Arenaceos: Univ. Central Venezuela, Ed. Biblioteca, Caracas, p. 270, fig. 25.

Large specimens are present in the Pleistocene section. Some of these exceed 4 mm in length. The species is abundant in the Recent moderately deep seas of the Caribbean-Antillean region, and specimens are also found in Middle Tertiary beds of that region. An excellent synonymy and reference list are given by Bermudez (1949, p. 80). Length of plesiotype, 1.53 mm; maximum breadth, 1.32 mm; thickness, 0.97 mm.

Neoeponides coryelli (Palmer)
Pl. X, figs. 11, 12

1945. *Eponides coryelli* Palmer, Bull. Amer. Paleontology, vol. 29, no. 115, p. 58, pl. 2, figs. 3, 4.

Identification of this species in the Louisiana Pleistocene was confirmed by comparison with topotypes from the Bowden Formation of Jamaica. The species is also present in the Miocene of Haiti and the Dominican Republic. Bermudez (1949, p. 245) gives a detailed synonymy. Maximum diameter of plesiotype, 0.84 mm; thickness, 0.61 mm.

Neoeponides parantillarum (Galloway and Heminway)
Pl. X, figs. 38, 39

1941. *Eponides parantillarum* Galloway and Heminway, New York Acad. Sci., Sci. Surv., Porto Rico and Virgin Is., vol. 3, pt. 4, p. 374, pl. 18, fig. 1.

Representatives of this species are abundant in several zones of the Pleistocene. Variation is noted in size and in the convexity of the spiral side. Maximum diameter of plesiotype, pl. X, figs. 38, 39, 0.57 mm; thickness, 0.36 mm.

The species has been identified in the Miocene of Puerto Rico, Jamaica, Venezuela, Trinidad, and the Dominican Republic and in the Pleistocene and Miocene (?) of Aruba.

NEOEPONIDES TUMIDULUS (H. B. Brady)
Pl. X, figs. 9, 10

1884. *Truncatulina tumidula* H. B. BRADY, Rept. Voy. Challenger, Zool., vol. 9, p. 666, pl. 95, figs. 8a-d.
1954. *Eponides tumidulus* (H. B. Brady). PARKER, Harvard, Bull. Mus. Comp. Zool., vol. 111, no. 10, p. 529, pl. 9, figs. 19, 24.

Small specimens occur in marine beds throughout the Pleistocene. These are typical of Recent specimens from the Gulf of Mexico which Parker figures in the above reference. According to Phleger and Parker (1951, p. 21), the species occurs in the northwest Gulf of Mexico at depths of 1000 meters or more. The types are from 2740 fathoms, southwest of the Canaries. Diameter of plesiotype, 0.17 mm; height, 0.13 mm.

NEOEPONIDES TURGIDUS (Phleger and Parker)
Pl. X, figs. 5, 6

1951. *Eponides turgidus* PHLEGER and PARKER, Geol. Soc. America, Mem. 46, pt. 2, p. 22, pl. 11, figs. 9a, b.

Identification of Pleistocene specimens is confirmed by comparison with holotype from the Gulf of Mexico. This species may belong to *Gyroidina* as stated in the above reference. Diameter of plesiotype, 0.13 mm; thickness, 0.06 mm.

NODOBACULARIELLA ATLANTICA Cushman and Hanzawa
Pl. IV, fig. 3

1937. *Nodobacullariella atlantica* CUSHMAN and HANZAWA, Contr. Cushman Lab. Foram. Res., vol. 13, p. 42, pl. 5, figs. 7, 8.

Although we are not clear as to the position of this species with respect to *N. cassis*, specimens are recognized in the Gulf Coast Pleistocene which seem to be close to the types of Cushman and Hanzawa from the eastern coast of the United States. Specimens from the Gulf of Mexico referred by Flint (1897, p. 302, pl. 47, fig. 4) to *Vertebralina insignis* H. B. Brady also belong here. Maximum diameter of plesiotype, 0.84 mm.

NODOBACULARIELLA CASSIS (d'Orbigny)
Pl. IV, fig. 4

1839. *Vertebralina cassis* D'ORBIGNY *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères", p. 51, pl. 7, figs. 14, 15.

Forms in which the early stages are indistinct are included in this species group. Costae may be fine to coarse, or they may be absent. The test is thicker than that of *N. atlantica* Cushman and Hanzawa. Cushman and Todd (1944, p. 68) observe a more strongly developed keel in *N. cassis* and a tendency in the adult for the final chamber to become rectilinear, but these features are shown by both species in our material.

D'Orbigny's types are from the shore sands of Cuba, and most of our specimens are referred to his species as herein interpreted rather than to *N. atlantica*. *N. cassis* is also reported from the Miocene of the Dominican Republic and from the Miocene and Pliocene of Florida. Maximum diameter of plesiotype, 0.76 mm.

NODOSARIA FUSTA Cushman and Todd
Pl. V, fig. 30

1945. *Nodosaria fusta* CUSHMAN and TODD, Cushman Lab. Foram. Res., Spec. Publ. 15, p. 28, pl. 4, figs. 20-22.

Pleistocene specimens were compared with topotypes from the Miocene of Buff Bay, Jamaica. Length of plesiotype (incomplete specimen), 1.91 mm; diameter, 0.38 mm.

NODOSARIA GRACILLIMA (Cushman and Jarvis)
Pl. IX, fig. 11

1934. *Ellipsonodosaria nuttalli* Cushman and Jarvis var. *gracillima* CUSHMAN and JARVIS, Contr. Cushman Lab. Foram. Res., vol. 10, pt. 3, no. 148, p. 72, pl. 10, figs. 7a, b.

Two specimens are referred to this species. One found at 3258 feet in the South Pass Block 41 well is slightly less than half as large as the holotype from the Miocene Cipero Formation of Trinidad, B.W.I. Specimens from the Miocene Buff Bay Formation of Jamaica are also approximately twice as large as our specimens, however the forms from the Pleistocene of Louisiana seem to be identical in other aspects with this Caribbean species. The individual found at 3490 feet differs from the type in having three spines on the initial end, two of which are weakly developed. Length of plesiotype, 0.42 mm; breadth, 0.11 mm.

This form is listed in figures 2 and 3 as *Nodosarella gracillima* (Cushman and Jarvis).

NODOSARIA HISPIDA d'Orbigny
Pl. V, fig. 31

1846. *Nodosaria hispida* D'ORBIGNY, Foram. Foss. Bass. Tert. Vienne, p. 35, pl. 1, figs. 24, 25.

The species was described from the Tertiary of Austria. It is recorded from the Middle Tertiary of Cuba and the Dominican Republic and from numerous Recent stations. Typical specimens have been found in the Gulf of Mexico (Flint, 1899, p. 311; Parker, 1954, p. 505). According to Parker in the latter reference, they occur deeper than 145 meters. The species has been observed by the writers in Miocene shales from wells off the coast of Louisiana. It is also known from the Miocene and Pliocene of the Mediterranean region and from the Calabrian of Italy. Length of plesiotype, 0.61 mm; diameter, 0.21 mm.

NODOSARIA PYRULA d'Orbigny
Pl. VI, fig. 19

1826. *Nodosaria pyrula* D'ORBIGNY, Ann. Sci. Nat., vol. 7, p. 253, no. 13.
1951. *Nodosaria pyrula* d'Orbigny. PHLEGER and PARKER, Geol. Soc. America, Mem. 46, part 2, p. 10, pl. 5, fig. 5.

Although our specimens from the Upper Pleistocene are broken, they show characteristics identical with those of Recent specimens from the Gulf of Mexico. The species has also been identified from the Recent of the Atlantic and from the Ki and Philippine Islands. The holotype is from the Upper Tertiary of Italy. Other Tertiary localities have been reported in Cuba, Trinidad, Jamaica, and the Dominican Republic. Length of figured fragment, 0.80 mm; maximum diameter, 0.15 mm.

NONIONELLA BASILOBA Cushman and McCulloch
Pl. VI, figs. 14, 15

1940. *Nonionella basiloba* CUSHMAN and MCCULLOCH, Allan Hancock Pacific Exped., vol. 6, no. 3, p. 162, pl. 18, figs. 3a-c.
1947. *Nonionella opima* CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 23, pt. 4, p. 90, pl. 20, figs. 1-3.
1954. *Nonionella opima* Cushman. PARKER, Harvard, Bull. Mus. Comp. Zool., vol. 111, no. 10, p. 507, pl. 6, figs. 10, 11, 12.
1961. *Nonionella basiloba* Cushman and McCulloch. ANDERSEN, Louisiana Dept. Cons., Geol. Bull. 35, pt. II, p. 85, pl. 18, figs. 5a-c.

This species was described from off the coast of California. Pleistocene specimens are typical of Recent specimens from the Atlantic and the Gulf of Mexico. Length of plesiotype, 0.23 mm; breadth, 0.17 mm; thickness, 0.13 mm.

This form is listed in figures 2 and 3 as *Nonionella opima* Cushman.

NONIONELLA sp.
Pl. VI, fig. 18

A few specimens occur in the Lower Pleistocene beds which, because of their scarcity, are not referred to a species. Length of figured specimen, 0.27 mm; breadth, 0.17 mm; thickness, 0.13 mm.

OOLINA HEXAGONA (Williamson)
Pl. VI, fig. 8

1848. *Entosolenia squammosa* Montagu var. *hexagona* WILLIAMSON, Ann. Mag. Nat. Hist., ser. 2, vol. 1, p. 20, pl. 2, fig. 23.

Several variants are assigned to this species. In the typical form, the hexagons are rather small and numerous. In another form, the hexagons are approximately twice as large and are less regular in shape than in the typical. Other features appear to be the same, and, because of the scarcity of specimens, it is not known whether this variation in the wall has significance. Length of plesiotype, 0.21 mm.

The species is reported from the Miocene of Florida, Jamaica, and the Dominican Republic. It has been identified in the Pliocene of Cuba and the Pleistocene of Florida. In Italy this form is recorded in the Upper Eocene, Upper Miocene, throughout the Pliocene, and in the Quaternary.

This species is listed in figures 2 and 3 as *Lagena hexagona* (Williamson).

ORIDORSALIS UMBONATUS ECUADORENSIS (Galloway and Morrey)
Pl. X, figs. 36, 37

1929. *Rotalia ecuadorensis* GALLOWAY and MORREY, Bull. Amer. Paleontology, vol. 15, no. 55, p. 26, pl. 3, figs. 13a-c.
1937. *Eponides umbonatus* (Reuss) var. *ecuadorensis* (Galloway and Morrey). HEDBERG, Jour. Paleontology, vol. 11, no. 8, p. 679, pl. 91, fig. 22.
1961. *Oridorsalis westi* Andersen, Louisiana Dept. Cons., Geol. Surv. Bull. 35, pp. 107-109, pl. 22, figs. 3a-c.

Hedberg points out in the reference above that material from the type locality of *Rotalina umbonata* Reuss at Hermsdorf, Germany, contains both specimens with nearly straight sutures and those with the characteristic curvature at their inner ends. We follow his conception of this form as an infraspecific group. This form or the typical is reported from the Gulf of Mexico at depths greater than 65 meters and from numerous Tertiary localities in the Mediterranean and Gulf of Mexico-Caribbean region. Maximum diameter of plesiotype, 0.38 mm; thickness, 0.20 mm.

PAVONINA ATLANTICA Cushman
Pl. IX, fig. 30)

1922. *Pavonina atlantica* CUSHMAN, U. S. Natl. Mus., Bull. 104, pt. 3, p. 51, pl. 19, fig. 1.
1932. *Pavonina miocenica* CUSHMAN and PONTON, Florida Geol. Survey, Bull. 9, p. 73, pl. 12, fig. 19.
1951. *Pavonina atlantica* Cushman. PHLEGER and PARKER, Geol. Soc. America, Mem. 46, pt. 2, p. 17, pl. 8, figs. 6, 7.

Our specimens were not compared with the type from off Sand Key, Florida, in 92 fathoms. The Pleistocene form, however, is identical with specimens from the Gulf of Mexico which are referred to this species by Phleger and Parker. Miss Ruth Todd compared the types of *P. atlantica* and *P. miocenica* (Miocene of Florida), and she has concluded that they are identical, no characters being evident by which the two can be specifically separated (personal communication). The range of *P. atlantica,* therefore, is here considered as Miocene to Recent. Additional Miocene occurrences are in Colombia, the Dominican Republic, and Jamaica. Length of plesiotype (broken specimen), 0.53 mm; breadth, 0.46 mm; thickness, 0.13 mm.

PENEROPLIS PROTEUS d'Orbigny
Pl. VII, figs. 1, 2

1839. *Peneroplis protea* D'ORBIGNY *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, Foraminifères, p. 60, pl. 7, figs. 7-11.

This species, described from Recent sediments of the Caribbean, is characteristic of Pleistocene carbonate zones. The range of the species is probably Miocene to Recent. It is recorded from the Miocene of the Dominican Republic and from the Miocene and Pliocene of Puerto Rico and the Gulf Coast. In Cuba it ranges throughout the post-Oligocene Cenozoic. Maximum diameter of plesiotype, pl. VII, fig. 2, 0.34 mm. Maximum diameter of plesiotype, pl. VII, fig. 1, 0.70 mm.

PLANORBULINA MEDITERRANENSIS
d'Orbigny
Pl. XV, fig. 15

1826. *Planorbulina mediterranensis* D'ORBIGNY, Ann. Sci. Nat., vol. 7, p. 280, no. 2, pl. 14, figs. 4-6 bis.; Modèles, no. 79.

According to Phleger (1951, p. 47), this species ranges from 20 to 200 meters in the Gulf of Mexico. Maximum diameter of plesiotype, 0.57 mm. The species is widely reported both from Recent and Tertiary sediments. In Italy the range is reported as Middle Miocene to Quaternary.

PLANULARIA QUASITRINAE Akers and
Dorman, n. sp.
Pl. V, figs. 5-7

Test almost twice as long as broad, very compressed, thin, sides almost parallel, early portion slightly inflated, coiled, later portion uncoiled; chambers numerous, about 20 in adult specimens, increasing gradually in length as added; peripheral margin with a rounded keel; sutures limbate; wall smooth.

Holotype and paratype from sidewall core at 2916 feet in California Company State Lease 1923, well No. 1, Dixon Bay Field, Plaquemines Parish, Louisiana. Dimensions of holotype (pl. V, figs. 5, 6): length, 1.26 mm; width, 0.69 mm; thickness, 0.21 mm. Length of paratype (fig. 7), 0.90 mm; width, 0.53 mm; thickness, 0.17 mm.

This species is similar to *P. trinae* Bermudez from the Tertiary of the Dominican Republic. *P. quasitrinae* is not so broad as *P. trinae,* and the keel is neither so wide nor sharp as in that species. Our holotype clearly shows 21 chambers; about ten may be observed in adult specimens of *P. trinae. P. quasitrinae* has been identified only in marine beds of Aftonian age.

PLANULINA EXORNA Phleger and Parker
Pl. XV, figs. 5, 6

1951. *Planulina exorna* PHLEGER and PARKER, Geol. Soc. America, Mem. 46, pt. 2, p. 32, pl. 18, figs. 5a, b, 6a, b, 7a, b, 8a, b.

This is the most frequent species of *Planulina* in our Pleistocene material. The species was described from the Gulf of Mexico where it is abundant in water shallower than

100 meters (Phleger, 1951, p. 48). Our specimens show variation in thickness and size of perforations. Maximum diameter of plesiotype, 0.36 mm; thickness, 0.10 mm.

PLANULINA FOVEOLATA (H. B. Brady)
Pl. XV, figs. 19, 20

1884. *Anomalina foveolata* H. B. BRADY, Rept. Voy. Challenger, Zool., vol. 9, p. 674, pl. 94, fig. 1.

This species, which was described from Recent sediments in the vicinity of Bermuda, occurs in marine zones throughout the Pleistocene. Phleger (1951, p. 48) reports it in the Gulf of Mexico deeper than 85 meters. The species is also reported from the Miocene of Haiti, the Dominican Republic, Cuba, and Jamaica. Maximum diameter of plesiotype, 0.59 mm; thickness, 0.24 mm.

PLECTOFRONDICULARIA FLORIDANA Cushman
Pl. VII, figs. 23, 24

1930. *Plectofrondicularia floridana* CUSHMAN, Florida Geol. Survey, Bull. 4, p. 41, pl. 8, fig. 1.

Specimens from the lowest marine zone of the Gulf Coast Pleistocene belong with this Miocene species from Walton County, Florida. The species is also recorded from the Tertiary of Bowden, Jamaica, the Dominican Republic, Colombia, Venezuela, Trinidad, and Barbados. *P. diversicostata* (Neugeboren), which has been identified in the Miocene of Hungary, Egypt, and Buff Bay, Jamaica, is similar to *P. floridana.* According to Cushman and Todd (1945, p. 38), *P. diversicostata* "resembles *P. floridana,* but is much slenderer, has larger and more numerous costae, and the test does not broaden as in that species." Length of plesiotype (broken specimen), 0.57 mm; maximum breadth, 0.21 mm.

POLYMORPHINA sp.

Rare specimens were found which are similar to *Pseudopolymorphina rutila* (Cushman) from the Byram Marl of Mississippi. Pleistocene specimens are more compressed than the Oligocene form, and they are too rare in our samples for the determination of specific characteristics.

POROEPONIDES CRIBROREPANDUS Asano and Uchio
Pl. XI, figs. 26, 27

1951. *Poroeponides cribrorepandus* ASANO and UCHIO *in* STACH, Illustrated Catalogue of Japanese Tertiary smaller Foraminifera, pt. 14, Rotaliidae p. 18, tfs. 134, 135.

The type figures for *Nautilus repandus* Fichtel and Moll are not clearly representative of our species, although many authors have identified Recent and Tertiary specimens with this species of Fichtel and Moll. Cushman (1931, p. 48) suggested that *Eponides* (?) *lateralis* (Terquem) might be a variety of the species of Fichtel and Moll. This possible relationship should be investigated.

Specimens here referred to *Poroeponides cribrorepandus* are found commonly in calcareous sediments in the Gulf of Mexico region. This relationship was observed in Recent sediments by Phleger and Parker (1951, p. 21). Our Pleistocene specimens show considerable variation in height, umbilical region, size, and limbate character of sutures. Pores on the apertural face are not always well developed even in large adult specimens. Asano and Uchio described this species from the Pliocene of Japan. It is also present in the Miocene of Japan, according to these authors. Maximum diameter of plesiotype, 0.71 mm.

PSEUDONODOSARIA COMATULA (Cushman)
Pl. V, figs. 28, 29

1923. *Nodosaria comatula* CUSHMAN, U. S. Natl. Mus., Bull. 104, pt. 4, p. 83, pl. 14, fig. 5.

Our specimens were compared with topotypes from 210 fathoms in the Gulf of Mexico which were supplied by Dr. A. R. Loeblich, Jr. This species has been reported from the Middle Tertiary of Trinidad, Mexico, Cuba, Venezuela, Jamaica, the Dominican Republic, and subsurface Louisiana. It is also reported from the Upper Eocene of Cuba (Bermudez, 1950, p. 354). Length of plesiotype (pl. V, fig. 28), 0.44 mm; diameter, 0.36 mm; length of plesiotype (pl. V, fig. 29), 0.78 mm; diameter, 0.38 mm.

This form is listed in figures 2 and 3 as *Nodosaria comatula* Cushman.

PULLENIA BULLOIDES (d'Orbigny)
Pl. XI, figs. 11, 12

1826. *Nonionina bulloides* D'ORBIGNY, Ann. Sci. Nat., vol. 7, p. 293.
1846. *Nonionina bulloides* D'ORBIGNY, Foram. Bass. Tert. Vienne, p. 107, pl. 5, figs. 9, 10.

Figures of the type from the Tertiary of Austria are also representative of our Pleistocene specimens. The species has been found from 65 meters to 1000 meters in the Gulf of Mexico, and it occurs in the Tertiary of California, Jamaica, Trinidad, Ecuador, Venezuela, Puerto Rico, the Dominican Republic, and Mexico. It is recorded throughout the post-Paleocene Cenozoic of Italy. Diameter of plesiotype, 0.29 mm; thickness, 0.25 mm.

PULLENIA QUINQUELOBA (Reuss)
Pl. XI, figs. 3, 15

1851. *Nonionina quinqueloba* REUSS, Zeitschr. deutsch. Geol. Ges., vol. 3, p. 71, pl. 5, fig. 31.

The type of this species is from the Tertiary of Hermsdorf, Germany. The name has been applied to groups from Recent sediments as well as from worldwide Tertiary localities. The species is recorded throughout the post-Paleocene Cenozoic of Italy. Our specimens are typical of those from the Gulf of Mexico to which the name has been applied. The species ranges from 50 meters to 2800 meters in the Gulf of Mexico (Phleger, 1951, p. 48). Diameter of plesiotype, 0.25 mm; thickness, 0.19 mm.

PULLENIA sp.
Pl. XI, fig. 2

Numerous specimens have been found in marine zones of the Pleistocene, but these have not been sufficiently frequent in any single sample to justify a description of the species. Diameter of figured specimen, 0.24 mm; thickness, 0.11 mm.

PYRGO CARINATA (d'Orbigny)
Pl. IV, figs. 11 ,12

1839. *Biloculina carinata* D'ORBIGNY *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères", p. 164, vol. 8, pl. 8, fig. 24; pl. 9, figs. 1, 2.

Specimens are probably conspecific with Recent forms from Cuba and Saint Thomas. This conclusion is reached on the basis of the figures by d'Orbigny. Length of plesiotype, 0.56 mm; breadth, 0.36 mm; thickness, 0.21 mm.

PYRGO COMATA (H. B. Brady)
Pl. IV, figs. 1, 2

1881. *Biloculina comata* BRADY, Quart. Journ. Micr. Sci., vol. 21, p. 45.
1884. *Biloculina comata* BRADY, Rept. Voy. Challenger, Zool., vol. 9, p. 144, pl. 3, fig. 9.

The species is recorded mostly from deep waters in the Atlantic and Caribbean. It has also been reported from the Middle Tertiary of the Dominican Republic. Length of plesiotype, 1.49 mm; breadth, 1.26 mm; thickness, 1.22 mm.

PYRGO MURRHINA (Schwager)
Pl. III, figs. 14, 15

1866. *Biloculina murrhina* SCHWAGER, Novara Exped. Geol. Theil., vol. 2, p. 203, pl. 4, figs. 15a-c.

In the north Atlantic, records for this species are deeper than 200 meters. It is not found shoaler than 45 meters in the Gulf of Mexico (Phleger, 1951, p. 48). Holotype is from the Miocene of Kar Nikobar. The species is reported from the Miocene of Haiti, Jamaica, and Trinidad. Length of plesiotype, 0.39 mm; breadth, 0.36 mm.

PYRGO NASUTUS Cushman
Pl. III, fig. 22

1935. *Pyrgo nasutus* CUSHMAN, Smithsonian Misc. Colln., vol. 91, no. 21, p. 7, pl. 3, figs. 1-4.

Pleistocene specimens are identical with Cushman's specimens from the area to the north of Puerto Rico. The distinctive bend of the test at the base of the aperture is present in our specimens as in the forms from the Recent of the Caribbean. Length of plesiotype, 0.23 mm; breadth, 0.13 mm.

PYRGO VESPERTILIO (Schlumberger)
Pl. III, figs. 29-32

1884. *Biloculina ringens* H. B. BRADY (not Lamarck), Rept. Voy. Challenger, Zool., vol. 9, p. 142, pl. 2, fig. 8.
1891. *Biloculina vespertilio* SCHLUMBERGER, Mem. Soc. Zool. France, vol. 4, p. 174, pl. 10, figs. 74-76, text figs. 20-22.
1917. *Biloculina vespertilio* Schlumberger. CUSHMAN, U. S. Natl. Mus., Bull. 71, pt. 6, p. 77, pl. 30, fig. 1; figs. 37-39 (in text).
1921. *Biloculina vespertilio* Schlumberger. CUSHMAN, U. S. Natl. Mus., Bull. 100, vol. 4, p. 472, pl. 95, figs. 5a, b.

This is a large robust form which has been reported mostly from fairly deep water in the Pacific. There seem to be no differences between our specimens and those figured by

Cushman in the above references. Length of plesiotype, pl. III, figs. 29, 30, 0.56 mm; breadth, 0.50 mm. Length of plesiotype, figs. 31, 32, 0.72 mm; breadth, 0.63 mm.

PYRGO sp. "A"
Pl. III, figs. 23, 24

Several rare specimens, similar to *P. nasutus,* are not speciated. Length of figured specimen, 0.61 mm; breadth, 0.53 mm; thickness, 0.42 mm.

PYRGO sp. "B"
Pl. III, figs. 33-35

A rare form in our material resembles *Pyrgo comata* but is probably distinct in having fewer costae and an elongation of the test at the aboral end. Length of figured specimen, 0.69 mm; breadth, 0.65 mm.

QUADRIMORPHINA VILARDEBOANA GLABRA (Cushman)
Pl. XI, figs. 28, 29

1927. *Valvulineria vilardeboana* (d'Orbigny) var. *glabra* CUSHMAN, Bull. California Univ., Scripps Inst. Oceanogr., Tech. Ser., vol. 1, p. 161, pl. 4, figs. 5, 6.
1951. *Valvulineria laevigata* PHLEGER and PARKER, Geol. Soc. America, Mem. 46, pt. 2, p. 25, pl. 13, figs. 11a, b, 12a, b.

Specimens are rare in Pleistocene samples. The thin, lobe-like umbilical plate is often broken in fossil specimens. This form is reported deeper than 120 meters in the Gulf of Mexico and from 300 meters to 680 meters on the Atlantic continental slope (Parker, 1948, p. 225). Maximum diameter of plesiotype, 0.23 mm; thickness, 0.14 mm.

This form is listed in figures 2 and 3 as *Valvulineria laevigata* Phleger and Parker.

QUINQUELOCULINA AGGLUTINANS d'Orbigny
Pl. II, figs. 24-26

1839. *Quinqueloculina agglutinans* D'ORBIGNY *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères", p. 195, pl. 12, figs. 11-13.

Our large agglutinated specimens seem to be identical with the type of d'Orbigny from Jamaica. Length of plesiotype, 1.41 mm; breadth, 0.99 mm. The species is also reported from the Pliocene of Florida (Cole, 1931, p. 19) and from the Lower Pliocene to the Quaternary of Italy.

QUINQUELOCULINA BICOSTATA d'Orbigny
Pl. II, figs. 27-29

1839. *Quinqueloculina bicostata* D'ORBIGNY *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères", p. 195, pl. 12, figs. 8-10.
1954. *Quinqueloculina bicostata* d'Orbigny. PARKER, Harvard, Bull. Mus. Comp. Zool., vol. 111, no. 10, p. 496, pl. 4, figs. 1, 2.

Pleistocene specimens like Recent specimens identified by Parker from the Gulf of Mexico are larger than those described by d'Orbigny from Cuba. Our specimens commonly attain a length of 1.3 mm. Length of plesiotype, 1.28 mm; breadth, 0.92 mm. The species is also reported from the Tertiary of Texas.

QUINQUELOCULINA HORRIDA Cushman
Pl. II, fig. 19

1947. *Quinqueloculina horrida* CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 23, pt. 4, p. 88, pl. 19, fig. 1.

Length of plesiotype, 0.27 mm; breadth, 0.20 mm. The types are from off the coast of Charleston, South Carolina, in 120 meters of water.

QUINQUELOCULINA LAMARCKIANA d'Orbigny
Pl. II, figs. 11-13

1839. *Quinqueloculina lamarckiana* D'ORBIGNY *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères", p. 189, pl. 11, figs. 14, 15.

This widely distributed Recent species is one of the most frequently seen throughout the Louisiana Pleistocene. It is recorded from the Middle Tertiary of the Louisiana Gulf Coast, Florida, Jamaica, Trinidad, Colombia, the Dominican Republic, and France and from the Pliocene and Pleistocene of Florida. It is known in the Calabrian of Italy. Length of plesiotype, 0.74 mm; breadth, 0.63 mm.

QUINQUELOCULINA POLYGONA d'Orbigny
Pl. II, figs. 21-23

1839. *Quinqueloculina polygona* D'ORBIGNY *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères", p. 198, pl. 12, figs. 21-23.

Pleistocene specimens are typical of the widely distributed Recent species of the West Indian Region. The species is also reported from the Middle Tertiary of Colombia, Jamaica, the Dominican Republic, and

France. Length of plesiotype, 0.60 mm; breadth, 0.29 mm.

RAMULINA GLOBULIFERA H. B. Brady
Pl. VI, fig. 25

1879. *Ramulina globulifera* H. B. BRADY, Quart. Journ. Micr. Sci., vol. 19, p. 58, pl. 8, figs. 32, 33.

The species has been recorded from both Atlantic and Pacific Oceans and from the Miocene of Mallorca, Spain, Jamaica, and the Dominican Republic; also Pliocene to Recent of Cuba; and Miocene and Pliocene of Italy. Length of plesiotype, 0.36 mm.

RECTOBOLIVINA ADVENA (Cushman)
Pl. IX, fig. 22

1922. *Siphogenerina advena* CUSHMAN, Carnegie Inst. Washington, Publ. 311, p. 35, pl. 5, fig. 2.

Pleistocene specimens were compared with the holotype, and they appear to be identical in every respect except size. The holotype is almost twice as long. Miocene occurrences are recorded for Jamaica and the Dominican Republic. A questionable specimen is reported from the Miocene Duplin Marl of South Carolina (Cushman and Cahill, 1933, p. 28). Length of homeotype, 0.39 mm; maximum breadth, 0.15 mm; thickness, 0.08 mm.

REUSSELLA MINUTA Drooger and Kaasschieter
Pl. IX, fig. 33

1958. *Reussella minuta* DROOGER and KAASSCHIETER, Reports of the Orinoco Shelf Expedition, vol. IV, p. 64, pl. 3, fig. 10.

This small foraminifer, described from the Orinoco-Trinidad-Paria shelf, has not been identified in the Recent of the Gulf of Mexico region. Disappearance or diminution in frequency of the species from the Gulf Coast region suggests that the environment here has changed since Pleistocene times. The species is reported as rare at several stations scattered between 35 and 200 meters on the Orinoco-Trinidad-Paria shelf, but we cannot be sure that these specimens, too, are not of Pleistocene age (Drooger and Kaasschieter, 1958, p. 93). Dimensions of plesiotype: length, 0.40 mm; diameter, 0.21 mm. Our figured specimen is much larger than those usually seen, the average length being in the vicinity of 0.20 mm. The maximum observed length reported by Drooger and Kaasschieter was 0.30 mm.

REUSSELLA MIOCENICA Cushman
Pl. IX, figs. 27, 28, 35

1945. *Reussella miocenica* CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 21, part 2, p. 36, pl. 6, figs. 19, 20.
1945. *Reussella aculeata* CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 21, part 2, p. 41, pl. 7, figs. 10, 11.
1947. *Reussella spinulosa* (Reuss) var. *atlantica* CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 23, pt. 4, p. 91, pl. 20, figs. 6, 7.
1951. *Reussella atlantica* Cushman. PHLEGER and PARKER (part), Geol. Soc. America, part 2, Mem. 46, p. 18, pl. 8, figs. 8, 9.

This species is rare in our Pleistocene samples. The species was described from the Miocene of Florida; it is also recorded from the Miocene of Colombia and Jamaica. Length of plesiotype (pl. IX, fig. 27), 0.49 mm; maximum breadth, 0.32 mm. Length of plesiotype (pl. IX, fig. 28), 0.36 mm; breadth, 0.29 mm. Length of plesiotype (pl. IX, fig. 35), 0.46 mm; breadth, 0.29 mm.

ROSALINA BULBOSA (Parker)
Pl. IX, figs. 14, 15

1954. *"Discorbis" bulbosa* PARKER, Harvard, Bull. Mus. Comp. Zool., vol. 111, no. 10, p. 523, pl. 8, figs. 10, 11, 12.

Numerous small specimens were found in the upper part of the cored section of the South Pass Block 41 well. Diameter of both plesiotypes, 0.21 mm; thickness, 0.15 mm.

ROSALINA CONCINNA (H. B. Brady)
Pl. IX, figs. 12, 13

1884. *Discorbina concinna* H. B. BRADY, Rept. Voy. Challenger, Zool. vol. 9, p. 646, pl. 90, figs. 7, 8.

A single but typical specimen was found at 592 feet in the South Pass Block 41 well. Maximum diameter of plesiotype, 0.27 mm.

ROSALINA FLORIDANA (Cushman)
Pl. IX, figs. 6, 7

1922. *Discorbis floridanus* CUSHMAN, Carnegie Inst. Washington, Publ. no. 311, p. 39, pl. 5, figs. 11, 12.

Only a few typical specimens were identified. The species is recorded from the Recent of the Antillean region, Florida, the north coast of Cuba, Rio de Janeiro Harbor, the Gulf of Mexico, and the Gulf of Paria. It is reported from the Pliocene and Pleistocene of Florida. Middle Tertiary occurrences are reported in Florida, Jamaica, Colombia, and the Dominican Republic. Maximum diameter of plesiotype, 0.29 mm.

ROSALINA FLORIDENSIS (Cushman)
Pl. IX, figs. 36, 37

1930. *Discorbis bertheloti* (d'Orbigny) var. *floridensis* CUSHMAN *in* CUSHMAN and JARVIS, Journ. Paleontology, vol. 4, no. 4, p. 364, pl. 33, figs. 13a-c.

Specimens are rare but typical of Recent specimens from south of Cape Hatteras. Miocene occurrences are reported for Colombia, Cuba, Jamaica, and the Dominican Republic. The species is reported from the Pleistocene of Aruba. Maximum diameter of plesiotype, 0.67 mm.

ROSALINA cf. R. NITIDA (Williamson)
Pl. IX, figs. 23, 24

1858. *Rotalina nitida* WILLIAMSON, Rec. Foram. Great Britain, p. 54, pl. 4, figs. 106-108.

A few Pleistocene specimens are referred tentatively to this species. Type specimens are not available for comparison, but our forms show a resemblance to the figures of Williamson. Maximum diameter of figured specimen, 0.34 mm.

ROSALINA cf. R. SUEZENSIS (Said)
Pl. X, figs. 24, 25

1949. *Discorbis suezensis* SAID, Cushman Lab. Foram. Res., Spec. Publ. 26, p. 36, pl. 3, fig. 34.

Our specimens are assigned questionably to this species; they are close to forms from the northern Red Sea and the Gulf of Mexico. Maximum diameter of plesiotype, 0.29 mm.

"ROTALIA" TRANSLUCENS Phleger and Parker
Pl. X, figs. 22, 23

1951. *"Rotalia" translucens* PHLEGER and PARKER, Geol. Soc. America, Mem. 46, pt. 2, p. 24, pl. 12, figs. 11a, b, 12a, b.

This common benthonic species from the Gulf of Mexico is also frequent in our fossiliferous Pleistocene cores. Maximum diameter of plesiotype, 0.27 mm.

SAGRINA PULCHELLA d'Orbigny
Pl. IX, figs. 8-10

1839. *Sagrina pulchella* D'ORBIGNY *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères", p. 150, pl. 1, figs. 23, 24.
1930. *Bolivina pulchella* (d'Orbigny) var. *primitiva* CUSHMAN, Florida Geol. Surv., Bull. 4, p. 47, pl. 8, figs. 12a, b.
1937. *Bolivina pulchella* (d'Orbigny). CUSHMAN, Cushman Lab. Foram. Res., Spec. Publ. 9, p. 151, pl. 15, figs. 9-11.

The type locality of this species was not designated. Recent localities given by d'Orbigny in the above reference are Cuba, St. Thomas, and Jamaica. Our Pleistocene specimens are identical with those from nearshore waters of the Gulf of Mexico. The holotype is not available for comparison, but it is our understanding (personal communication, A. R. Loeblich, Jr., 1958) that the holotype is identical with Recent specimens from the Gulf of Mexico-Caribbean and with specimens from the Miocene of Florida identified as *Bolivina pulchella primitiva* Cushman. As *Bolivina pulchella* (d'Orbigny), the form has been recorded from the Miocene of Jamaica and the Dominican Republic. It is also recorded from the Pliocene of Cuba and Florida. Length of plesiotype (pl. IX, fig. 8), 0.25 mm; breadth, 0.20 mm. Length of plesiotype (pl. IX, figs. 9, 10), 0.19 mm; breadth, 0.07 mm.

SARACENARIA ITALICA Defrance
Pl. VI, figs. 20-22

1824. *Saracenaria italica* DEFRANCE, Dict. Sci. Nat., vol. 32, p. 177.

The range of variation of this widely reported species is not understood. Its reported stratigraphic range is Lower Oligocene to Recent. Middle Tertiary occurrences are recorded from Florida, Louisiana, Italy, Cuba, Jamaica, and the Dominican Republic. The range in Italy is Helvetian to Quaternary. Specimens from the Louisiana Pleistocene are large and typical of the forms usually referred to the species. Length of plesiotype, 1.58 mm.

SARACENARIA sp. "A"
Pl. VI, figs. 2, 3

A specific determination is not made for the rare specimens of this group. Length of figured specimen, 0.42 mm.

SARACENARIA sp. "B"
Pl. VI, fig. 1

Rare specimens of this group are distinctive, but a specific determination is not made due to infrequent occurrence. Length of figured specimen, 0.68 mm.

SARACENARIA sp. "C"
Pl. VI, fig. 7

This form may be the same as that referred by Cushman to *Cristellaria schloenbachi.* Specimens are rare. Length of figured specimen, 0.27 mm.

SIGMOILINA DISTORTA Phleger and Parker
Pl. II, figs. 9 ,10

1951. *Sigmoilina distorta* PHLEGER and PARKER, Geol. Soc. Amer., Mem. 46, pt. 2, p. 8, pl. 4, figs. 3-5.

The Pleistocene form is closer to this species than to the larger, more compressed *S. tenuis* (Czjzek). *S. distorta* may be present in the Miocene of various localities in the Gulf Coast and West Indies but reported as *Sigmoilina tenuis* (Czjzek). Length of plesiotype, 0.34 mm; breadth, 0.17 mm.

SIGMOILOPSIS SCHLUMBERGERI
(A. Silvestri)
Pl. II, figs. 16-18

1904. *Sigmoilina schlumbergeri* A. SILVESTRI, Mem. Pont. Accad. Nuovi Lincei, vol. 22, p. 267.

The reported range of this species is Middle Tertiary to Recent. Middle Tertiary occurrences are reported for Haiti, the Dominican Republic, Cuba, Jamaica, and Trinidad. Length of plesiotype, 1.09 mm; breadth, 0.78 mm.

SIGMOILOPSIS SUBPOEYANA (Cushman)
Pl. II, fig. 7

1922. *Quinqueloculina subpoeyana* CUSHMAN, Carnegie Inst. Washington, Publ. 311, p. 66; U. S. Natl. Mus., Bull. 104, pt. 6, p. 31, pl. 5, fig. 3.
1956. *Sigmoilina subpoeyana* (Cushman). BANDY, U. S. Geol. Survey, Prof. Paper 274-G, p. 197, pl. 29, fig. 1.

Bandy in the above reference is followed in assigning specimens to this species rather than to *Spiroloculina antillarum* d'Orbigny. *S. subpoeyana* is recorded from the Miocene of Florida and northern Colombia. Length of plesiotype, 0.46 mm; breadth, 0.23 mm.

SIPHOGENERINA RAPHANUS (Parker and Jones)
Pl. IX, fig. 25

1865. *Uvigerina (Sagrina) raphanus* PARKER and JONES, Phil. Trans., p. 364, pl. 18, figs. 16, 17.
1913. *Siphogenerina raphanus* (Parker and Jones). CUSHMAN, U. S. Natl. Mus., Bull. 71, part 3, p. 108, pl. 46, figs. 1-5.
1923. *Siphogenerina raphanus* (Parker and Jones). CUSHMAN, U. S. Natl. Mus., Bull. 104, pt. 4, p. 174, pl. 42, fig. 14.
1935. *Siphogenerina raphanus* (Parker and Jones). BERMUDEZ, Mem. Soc. Cubana Hist. Nat., vol. 9, p. 199.
1945. *Siphogenerina* cf. *S. raphanus* (Parker and Jones). D. K. PALMER, Bull. Amer. Paleontology, vol. 29, no. 115, p. 52.
1949. *Siphogenerina raphanus* (Parker and Jones). BERMUDEZ, Cushman Lab. Foram. Res., Spec. Publ. 25, p. 222, pl. 14, fig. 18.

Comparison with material at the U. S. National Museum shows that our specimens are typical of this slender, widely distributed form. In the Gulf Coast Pleistocene, occurrences are in the lower marine shales. The species has been reported from Recent sediments of the Pacific and Atlantic Oceans and from the north coast of Cuba. It has also been reported from the Miocene of Jamaica and the Dominican Republic and from the Pliocene of Cuba. Length of plesiotype (broken specimen), 0.69 mm; diameter, 0.27 mm.

SIPHONINA PULCHRA Cushman
Pl. XI, figs. 13, 14

1919. *Siphonina pulchra* CUSHMAN, Carnegie Inst. Washington, Publ. 291, p. 42, pl. 14, fig. 7.

This is a common species in the Gulf of Mexico. Middle Tertiary occurrences are reported from Cuba, Haiti, Jamaica, Trinidad, Colombia, and the Dominican Republic. Cole (1931, p. 51) reports the species from the Pliocene of Florida. Maximum diameter of plesiotype, 0.46 mm; thickness, 0.22 mm.

SIPHONODOSARIA ANTILLEA (Cushman)
Pl. IX, fig. 34

1923. *Nodosaria antillea* CUSHMAN, U. S. Natl. Mus., Bull. 104, pt. 4, p. 91, pl. 14, fig. 9.

In the Gulf Coast Pleistocene, this species has not been found higher than the lowermost marine beds. The type specimen is from 307 meters off the eastern coast of the United States. The species is also recorded from off Brazil in 1234 meters and from possible Miocene in a well in Aruba (Drooger, 1953, p. 137). Length of plesiotype, 0.76 mm. Diameter of largest chamber, 0.19 mm.

SIPHONODOSARIA VERNEUILI (d'Orbigny)
Pl. IX, fig. 39

1846. *Dentalina verneuili* D'ORBIGNY, Foram. Foss. Bass. Tert. Vienne, p. 48, pl. 2, figs. 7, 8.
1928. *Nodosaria verneuili* (d'Orbigny). NUTTALL, Quart. Journ. Geol. Soc., vol. 84, p. 81, pl. 4, figs. 14, 15.

1929. *Ellipsonodosaria verneuili* (d'Orbigny). CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 5, p. 96, pl. 14, figs. 1-3.
1941. *Nodosarella verneuili* (d'Orbigny). GALLOWAY and HEMINWAY, New York Acad. Sci., Sci. Survey Porto Rico and Virgin Is., vol. 3, pt. 4, p. 440, pl. 35, fig. 10.
1948. *Ellipsonodosaria verneuili* (d'Orbigny). RENZ, Geol. Soc. Amer., Mem. 32, p. 131, pl. 8, figs. 3-5.

There are no significant differences between our Pleistocene specimens and forms in our collection from Italy and Baden, Austria. The species was described from the Miocene of the Vienna basin. It has been reported from the Eocene and Oligocene (?) of Cuba and Venezuela and from Eocene to Miocene in Italy. It is recorded from the Middle Tertiary of Puerto Rico, Trinidad, Ecuador, the Dominican Republic, Jamaica, and Sumatra. Length of fragment, 0.78 mm; diameter, 0.19 mm .

SIPHOTEXTULARIA AFFINIS (Fornasini)
Pl. I, fig. 13

1883. *Sagraina affinis* FORNASINI, Boll. Soc. Geol. Ital., vol. 2, p. 14, pl. 2, figs. 10a-c.

This species is recorded from the Gulf of Mexico and from off the northeast coast of the United States from 90 meters to 300 meters. The type is from the Pliocene of Italy. It is reported from the Miocene of Mallorca by Colom (1946, p. 119). Length of plesiotype, 0.32 mm; breadth, 0.25 mm; thickness, 0.18 mm.

SIPHOTEXTULARIA ROLSHAUSENI Phleger and Parker
Pl. I, fig. 14

1951. *Siphotextularia rolshauseni* PHLEGER and PARKER, Geol. Soc. America, Mem. 46, part 2, p. 4, pl. 1, figs. 23, 24a, b.

Length of plesiotype, 0.25 mm; breadth, 0.17 mm; thickness, 0.11 mm.

SORITES MARGINALIS (Lamarck)
Pl. VII, fig. 18

1816. *Orbulites marginalis* LAMARCK, Syst. Anim. sans Vert., vol. 2, p. 196, no. 1.

This species, described from the Recent of the European region, occurs in abundance in the uppermost beds of the Gulf Coast Pleistocene. These specimens are typical of those from the Gulf of Mexico-Caribbean waters. The species is reported from Upper Oligocene to Upper Miocene in the Dominican Republic. Specimens from the Miocene of Florida and Louisiana referred to in the literature as *Sorites* sp. may belong to this species. The range in Cuba is Miocene to Recent. It also occurs in the Pliocene of Florida. Maximum diameter of plesiotype, 1.12 mm.

SPHAEROIDINA BULLOIDES d'Orbigny
Pl. XI, figs. 9, 10

1826. *Sphaeroidina bulloides* D'ORBIGNY, Ann. Sci. Nat., vol. 7, p. 267, Modèles, no. 65.

This species is recorded from the Middle Tertiary of California, Louisiana, Cuba, Jamaica, and the Dominican Republic, as well as from modern seas. It is reported from Lower Oligocene to Quaternary in Italy. Maximum diameter of plesiotype, 0.36 mm.

SPIRILLINA VIVIPARA Ehrenberg
Pl. IX, fig. 21

1843. *Spirillina vivipara* EHRENBERG, (1841), Abhandl. k. Akad. Wiss. Berlin, Theil. 1, pp. 323, 422, pl. 3, sec. 7, fig. 41.

Our Pleistocene specimens are small, rare, and usually broken. They are close in appearance to specimens from the Gulf of Mexico. The species is reported from the Miocene of Cuba, the Upper Eocene and Lower Oligocene of Puerto Rico, and questionably from the Anahuac Formation of the Gulf Coast. Diameter of plesiotype, 0.17 mm.

SPIROLOCULINA DEPRESSA d'Orbigny
Pl. II, fig. 8

1826. *Spiroloculina depressa* D'ORBIGNY, Ann. Sci. Nat., ser. 1, tome 7, p. 298; Modèles, no. 92.
1956. *Spiroloculina depressa* d'Orbigny. BANDY, U. S. Geol. Survey, Prof. Paper 274-G, p. 197, pl. 29, fig. 2.

The species has been reported from various European Pliocene and Miocene localities as well as from modern seas (Cushman and Todd, 1944, p. 28). A similar, perhaps conspecific form, *S. alveata* Cushman and Todd, is recorded from the Miocene of Florida and Jamaica. *S. depressa* has been identified in the Pliocene and Pleistocene of Italy. Length of plesiotype, 0.34 mm; breadth, 0.25 mm; thickness, 0.07 mm.

STETSONIA MINUTA Parker
Pl. XI, figs. 20, 21

1954. *Stetsonia minuta* PARKER, Harvard, Bull. Mus. Comp. Zool., vol. 111, no. 10, p. 534, pl. 10, figs. 27, 28, 29.

Specimens are small and rare as in Recent sediments of the Gulf of Mexico. These qualities may have precluded the observation of this species in Tertiary or other Recent samples. Diameter of plesiotype, 0.11 mm; thickness, 0.06 mm.

TEXTULARIA CANDEIANA d'Orbigny
Pl. I, figs. 4, 5

1839. *Textularia candeiana* D'ORBIGNY *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères", p. 143, pl. 1, figs. 25-27.

The recorded range of this species is Oligocene to Recent. Middle Tertiary occurrences are reported for Florida, Puerto Rico, Jamaica, and the Dominican Republic. It is reported from the Pliocene of Cuba. Length of plesiotype, 0.53 mm; breadth, 0.46 mm; thickness, 0.31 mm.

TEXTULARIA CONICA d'Orbigny
Pl. I, figs. 2, 3

1839. *Textularia conica* D'ORBIGNY *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères", p. 143, pl. 1, figs. 19, 20.

T. conica is recorded from the Middle Tertiary of Florida, the *Heterostegina* Limestone of Texas and Louisiana, and from the Pleistocene of Italy and Aruba, as well as from Recent sediments of the Caribbean. It is also reported from the Pliocene of Cuba and from possible Miocene of Aruba. Length of plesiotype, 0.53 mm; breadth, 0.63 mm; thickness, 0.53 mm.

TEXTULARIA FOLIACEA OCCIDENTALIS Cushman
Pl. I, figs. 10, 11

1922. *Textularia foliacea* Heron-Allen and Earland var. *occidentalis* CUSHMAN, U. S. Natl. Mus., Bull. 104, pt. 3, p. 16, pl. 2, fig. 13.

This foraminifer occurs in several carbonate zones of the Pleistocene. It is easily confused with *T. sica* Lalicker and Bermudez but is not so compressed as that species. The types are from off the coast of Cuba in 45 fathoms. Miocene occurrences are reported from Florida and Jamaica. Length of plesiotype, 0.69 mm; breadth, 0.42 mm; thickness, 0.27 mm.

TEXTULARIA MAYORI Cushman
Pl. I, fig. 12

1922. *Textularia mayori* CUSHMAN, Carnegie Inst. Wash., vol. 17, p. 23, pl. 2, fig. 3.

The species is recorded from the Miocene and Pliocene of Florida. Length of plesiotype, 1.13 mm; breadth, 0.92 mm; thickness, 0.57 mm.

TEXTULARIA MEXICANA Cushman
Pl. I, fig. 6

1896. *Textularia rugosa* Reuss, var., GOES, Harvard, Bull. Mus. Comp. Zool., vol. 29, p. 43, pl. 5, figs. 4, 5.
1899. *Textularia carinata* FLINT (not d'Orbigny), Rept. U. S. Natl. Mus., (1897), pt. 2, p. 284, pl. 29, fig. 1.
1922. *Textularia mexicana* CUSHMAN, U. S. Natl. Mus., Bull. 104, pt. 3, p. 17, pl. 2, fig. 9.
1941. *Textularia mexicana* LALICKER and BERMUDEZ, Torreia, Habana, no. 8, p. 15, pl. 4, fig. 3.
1945. *Textularia mexicana* CUSHMAN and TODD, Cushman Lab. Foram. Res., Spec. Publ. 15, p. 1, pl. 1, fig. 1.
1940. *Textularia warrenites* CORYELL and RIVERO, Journ. Paleontology, vol. 14, p. 325, pl. 41, fig. 4.

Our specimens are typical of those from the Recent of the Gulf of Mexico and the Caribbean Sea. The species is also reported from the Miocene of California, France, and the Caribbean region, and we have seen typical specimens in the subsurface Louisiana Pliocene and Miocene. Length of plesiotype, 0.86 mm; breadth, 0.64 mm; thickness at median line, 0.42 mm.

TEXTULARIA SICA Lalicker and Bermudez
Pl. I, figs. 8, 9

1941. *Textularia sica* LALICKER and BERMUDEZ, Torreia, no. 8, p. 16, pl. 4, figs. 5, 6.

This compressed *Textularia* is a distinctive species in the upper portion of the marine Pleistocene. The types are from off the North coast of Cuba in 230 fathoms. Length of plesiotype, 0.67 mm; breadth, 0.42 mm; thickness, 0.17 mm.

TEXTULARIA cf. T. YAGUATENSIS Bermudez
Pl. I, fig. 7

1949. *Textularia yaguatensis* BERMUDEZ, Cushman Lab. Foram. Res., Spec. Publ. 25, p. 64, pl. 2, figs. 63-65.

The species to which our Lower Pleistocene specimens are questionably referred was described from the Middle Tertiary of the Dominican Republic. Length of figured

specimen, 0.42 mm; breadth, 0.39 mm; thicnkess, 0.17 mm.

TEXTULARIELLA BARRETTII (Jones and Parker)
Pl. I, figs. 26, 27

1863. *Textularia barrettii* JONES and PARKER, Rept. British Association Newcastle Meeting, pp. 80-105.

Very large specimens are characteristic of the upper marine zones of the Louisiana Pleistocene. The species was described from the Recent of Jamaica. The recorded range is Upper Oligocene to Recent. Middle Tertiary specimens have been reported from Cuba, Jamaica, Venezuela, and the Dominican Republic. The species is also present in the Miocene of Louisiana and the Pliocene of Cuba. Length of plesiotype, 1.26 mm; diameter, 1.32 mm. Specimens twice the size of our plesiotype are common in the upper zones of the Pleistocene of the lower Mississippi River delta.

TRIFARINA BELLA (Phleger and Parker)
Pl. IX, fig. 32

1951. *Angulogerina bella* PHLEGER and PARKER, Geol. Soc. America, Mem. 46, pt. 2, p. 12, pl. 6, figs. 7, 8.

This species is usually present in marine zones throughout the Pleistocene. Specimens are always small as are Recent members of the species in the Gulf of Mexico. Sharply undercut chambers with pointed projections are typical in our specimens, but low costae are sometimes present so that specimens resemble *A. jamaicensis* Cushman and Todd in this single respect. Length of plesiotype, 0.40 mm.

TRIFARINA EXIMIA (Cushman and Jarvis)
Pl. IX, fig. 19

1936. *Angulogerina eximia* CUSHMAN and JARVIS, Contr. Cushman Lab. Foram. Res., vol. 12, p. 3, pl. 1, figs. 11, 12.

Miocene specimens from the type locality near Buff Bay, Jamaica, reach a length of half again that of our Pleistocene specimens. The Jamaican specimens are also generally more robust, but considerable variation exists in this respect, and our specimens fall within the range of this variation. Pleistocene specimens possibly constitute a subspecies, as perhaps may also the Tertiary Haitian specimens reported by Coryell and Rivero (1940, p. 342) as suggested by Bermudez (1949, p. 214). This foraminifer is also recorded from the Miocene of Cuba. It is rare here except in the core at 2418 feet, California Company State Lease 2553 no. 1. Length of plesiotype, 0.38 mm; breadth, 0.19 mm.

TRIFARINA HOLCKI Akers and Dorman, n. sp.
Pl. IX, figs. 16-18

Test small, stout, fusiform, subtriangular in transverse section, angles so poorly developed in some specimens as to suggest *Uvigerina,* microspheric individuals slightly more than half as broad as long, megalospheric individuals twice as long as broad, maximum width midway of the test; chambers inflated, with slightly depressed sutures; surface bearing numerous, very fine, sometimes indistinct costae, which continue to the base of the neck; aperture terminal with a short neck bearing a slight but definite lip; dimensions of holotype, pl. IX, fig. 17: length including neck, 0.40 mm; breadth, 0.22 mm. Length of paratype, pl. IX, fig. 16, 0.42 mm; breadth, 0.29 mm. Length of paratype, pl. IX, fig. 18, 0.36 mm; breadth, 0.21 mm.

Holotype and paratypes are from the core at 3560 feet in California Company State Lease 2553, well number 1, South Pass Block 41, Plaquemines Parish, Louisiana. This species is restricted in the Louisiana Pleistocene to a zone of only a few hundred feet in thickness (Aftonian, Akers and Holck, 1957), but laterally it has been found in wells in the lower Mississippi delta and in wells off the entire length of the Louisiana coast. It is named in recognition of the work of A. J. J. Holck on the Louisiana Pleistocene.

The species is similar to the larger *Trifarina multistriata* (Bermudez) from the Tertiary of the Dominican Republic. It is less angulate, and the chambers are more bulbous than in *T. multistriata.*

TRILOCULINA CIRCULARIS Bornemann
Pl. III, figs. 12, 13

1855. *Triloculina circularis* BORNEMANN, Zeitschr. deutsch. geol. Ges., vol. 7, p. 349.
1917. *Triloculina circularis* Bornemann. CUSHMAN, U. S. Natl. Mus., Bull. 71, pt. 6, p. 67, pl. 25, fig. 4; pl. 26, fig. 1.

Our specimens are close to the Caribbean form. The species has been reported from the Pliocene and Pleistocene of Florida and from the Miocene of Puerto Rico and

France. It has also been identified in the Calabrian of Italy. Length of plesiotype, 0.29 mm; breadth, 0.27 mm; thickness, 0.22 mm.

TRILOCULINA INSIGNIS (H. B. Brady)
Pl. III, figs. 16-18

1881. *Miliolina insignis* BRADY, Quart. Journ. Micr. Sci., London, n. s., vol. 21, p. 45.
1884. *Miliolina insignis* BRADY, Rept. Voy. Challenger, Zool., vol. 9, p. 165, pl. 4, figs. 8, 10.

Our specimens, except for variation in the apertural tooth, seem to be identical with Brady's types from Recent sediments off Culebra Island in 390 fathoms. Length of plesiotype, 0.99 mm; breadth, 0.84 mm; thickness, 0.98 mm.

TRILOCULINA TRICARINATA d'Orbigny
Pl. III, fig. 21

1826. *Triloculina tricarinata* D'ORBIGNY, Ann. Sci. Nat., tome 7, p. 299, Modèles no. 94.

Pleistocene specimens are typical of the widely distributed group which has been referred to this species. D'Orbigny's type is from the Red Sea. The species is recorded from the Middle Tertiary of Venezuela, Trinidad, Puerto Rico, Jamaica, and France and from the Pliocene of Florida. It is also reported from the Pliocene and Pleistocene of Italy. Length of plesiotype, 0.86 mm; diameter, 0.59 mm.

TRILOCULINA TRIGONULA (Lamarck)
Pl. III, figs. 19, 20

1804. *Miliolites trigonula* LAMARCK, Ann. du Mus., vol. 5, p. 351, no. 3.
1826. *Triloculina trigonula* D'ORBIGNY, Ann. Sci. Nat., vol. 7, p. 299, no. 1, pl. 16, figs. 5-9; Modèles, no. 93.

Our specimens are typical of those from the Recent of the Atlantic Ocean and the Gulf of Mexico which have been referred to this species. The holotype is from the Eocene of the Paris Basin, however, and it is doubtful if the species is adequately understood. *T. trigonula* has been reported from the Middle Tertiary of Trinidad; from the Miocene and Pliocene of Florida; and from the Pliocene and Pleistocene of Italy. Length of plesiotype, 0.67 mm; breadth, 0.57 mm; thickness, 0.63 mm.

TRIMOSINA DENTICULATA Akers and Dorman, n. sp.
Pl. IX, figs. 2-5

Test small, elongate to tapering ovate, broadest between the middle and the apertural end, triserial, angular; sutures distinct; final three chambers inflated and abruptly enlarged, each chamber bearing a downward pointing spine at the marginal angle and several shorter protuberances on the remainder of the wall, initial chamber with an acicular spine; aperture a wide loop-like opening with a thin lip and a narrow plate-like tooth.

Holotype and paratype from California Company State Lease 2553, well no. 1, South Pass Block 41 Field, sidewall core at 3460 feet. Length of holotype (pl. IX, figs. 2, 4), 0.32 mm; diameter, 0.21 mm. Paratype (pl. IX, fig. 5), 0.25 mm in length. Paratype (pl. IX, fig. 3), 0.32 mm in length.

Specimens are particularly frequent in the deep water deposits of Aftonian age. The species seems to have become extinct before the end of the last glacial stage. We have not seen it in Gulf Coast Miocene or Caribbean Tertiary, but it also occurs in the Louisiana Pliocene.

TRITAXIA MEXICANA (Cushman)
Pl. I, figs. 20, 21

1922. *Clavulina humilis* H. B. Brady var. *mexicana* CUSHMAN, U. S. Natl. Mus., Bull. 104, pt. 3, p. 83, pl. 16, figs. 1-3.

Individuals are variable in size as may be seen by figures 20 and 21, pl. I. The species has been reported from the Gulf of Mexico between 30 meters and 675 meters. In the West Indian region occurrences have been reported from 124 meters to 2431 meters. Tertiary occurrences are reported from California, Cuba, Jamaica, Aruba, and the Dominican Republic. Length of plesiotype, pl. I, fig. 20, 1.20 mm; maximum breadth, 0.48 mm. Length of plesiotype, pl. I, fig. 21, 0.71 mm; maximum breadth, 0.25 mm.

This form is listed in figures 2 and 3 as *Clavulina mexicana* Cushman.

TRITAXILINA YASICAENSIS Bermudez
Pl. II, figs. 3, 4

1949. *Tritaxilina yasicaensis* BERMUDEZ, Cushman Lab. Foram. Res., Spec. Publ. 25, p. 96, pl. 5, figs. 55, 56.

Rare specimens are referred to this species described by Bermudez from the Middle

Tertiary of the Dominican Republic. Length of plesiotype, 0.84 mm; diameter, 0.49 mm.

TUBINELLA cf. T. FUNALIS (H. B.. Brady)
Pl. III, fig. 7

1884. *Articulina funalis* H. B. BRADY, Rept. Voy. Challenger, Zool., pt. 22, vol. 9, p. 185, pl. 13, figs. 6-11.

This species was described from Recent sediments in the vicinity of Prince Edward Island, Indian Ocean. Our specimens are somewhat smaller than the holotype. Length of figured specimen (broken), 0.59 mm.

TURRILINA sp.
Pl. VII, fig. 25

A single, small specimen is assigned to this genus. Length of figured specimen, 0.17 mm; diameter, 0.07 mm.

UVIGERINA BELLULA Bandy
Pl. IX, fig. 1

1956. *Uvigerina bellula* BANDY, U. S. Geol. Surv., Prof. Paper 274-G, p. 199, pl. 31, fig. 13.

This small *Uvigerina* occurs throughout the marine Pleistocene section. The species has been reported from the Gulf of Mexico, the Caribbean, and the Pacific Ocean as *U. auberiana* d'Orbigny var. *laevis* Goës. Length of plesiotype, 0.30 mm; breadth, 0.13 mm.

UVIGERINA FLINTII Cushman
Pl. IX, fig. 29

1923. *Uvigerina flintii* CUSHMAN, U. S. Natl. Mus., Bull. 104, pt. 4, p. 165, pl. 42, fig. 13.

Tertiary specimens are reported from Italy, the Georges Bank Canyons, and the Dominican Republic. Length of homeotype, 0.59 mm; breadth, 0.34 mm. Our specimens were compared with the holotype and paratypes from the Recent of the Antillean-Caribbean region. Specimens from the Tertiary Buff Bay of Jamaica referred to *U. laviculata* Coryell and Rivero differ only in being more finely costate.

UVIGERINA PEREGRINA Cushman
Pl. IX, fig. 26

1923. *Uvigerina peregrina* CUSHMAN, U. S. Natl. Mus., Bull. 104, pt. 4, p. 166, pl. 42, figs. 7-10.
1940. *Uvigerina peregrina* CORYELL and RIVERO (not Cushman), Journ. Paleontology, vol. 14, p. 343, pl. 44, fig. 19.
1940. *Uvigerina pigmaea* CORYELL and RIVERO (not d'Orbigny), Journ. Paleontology, vol. 14, p. 343, pl. 44, fig. 20.
1941. *Uvigerina peregrina* Coryell and Rivero. CUSHMAN and TODD (part), Contr. Cushman Lab. Foram. Res., vol. 17, p. 51, pl. 14, figs. 14, 15 (not figs. 16, 17).
1941. *Uvigerina gardnerae* GALLOWAY and HEMINWAY (not Cushman), New York Acad. Sci., Sci. Surv., Porto Rico and Virgin Is., vol. 3, pt. 4, p. 429, pl. 33, fig. 13.
1942. *Uvigerina gallowayi* CORYELL and MOSSMAN (not Cushman), Journ. Paleontology, vol. 16, p. 244, pl. 36, fig. 50.
1945. *Uvigerina hispido-costata* CUSHMAN and TODD, Cushman Lab. Foram. Res., Spec. Publ. 15, p. 51, pl. 7, figs. 27, 31.

This assignment is made for a variable group of specimens. The term morphotype in the sense of Sylvester-Bradley (1958, p. 217) probably should be used here instead of species in the biologic sense. Even specimens of this group from the Gulf of Mexico show variation in development of costae and spines, and it is difficult to determine specific or infraspecific groups. There may be several species in the above synonymy, but all possess similarities of test form which distinguish the group from other *Uvigerinas*. Specimens of this general group are recorded from Middle Tertiary sediments of the Gulf Coast and the Caribbean region. In Italy the range is Tortonian to Quaternary. Length of plesiotype, 0.44 mm; diameter, 0.25 mm.

UVIGERINA PEREGRINA BRADYANA Cushman
Pl. IX, fig. 38

1923. *Uvigerina peregrina* Cushman var. *bradyana* CUSHMAN, U. S. Natl. Mus., Bull. 104, pt. 4, p. 168, pl. 42, fig. 12.

This variant is recorded from the Tertiary of California and from the Pliocene of Florida. It was described from the Atlantic Ocean. Length of plesiotype, 0.27 mm; diameter, 0.13 mm.

UVIGERINA PEREGRINA PARVULA Cushman
Pl. IX, fig. 31

1923. *Uvigerina peregrina* Cushman var. *parvula* CUSHMAN, U. S. Natl. Mus., Bull. 104, pt. 4, p. 168, pl. 42, fig. 11.

Several variants may be recognized in this group on the basis of the costae which are more numerous and finer in some specimens than in others as observed by Parker (1954, p. 521) in material from the northeastern Gulf of Mexico. This foraminifer has been

reported from the Miocene of Jamaica and from the Pliocene and Pleistocene of California. Length of plesiotype, 0.53 mm; diameter, 0.21 mm.

VAGINULINOPSIS PLANATA (Phleger and Parker)
Pl. VI, figs. 34, 35

1951. *Marginulina planata* PHLEGER and PARKER, Geol. Soc. America, Mem. 46, part 2, p. 9, pl. 4, figs. 21, 22; pl. 5, figs. 1-3.

Large compressed specimens from the upper part of the Pleistocene are typical of Recent specimens from the Gulf of Mexico. Length of plesiotype, 3.02 mm; maximum breadth, 0.90 mm; thickness, 0.50 mm.

VALVULINERIA HERRICKI (Hadley)
Pl. X, figs. 16, 17

1934. *Cibicorbis herricki* HADLEY, Bull. Amer. Paleontology, vol. 20, no. 70A, p. 26, pl. 5, figs. 1-3.
1949. *Cibicorbis herricki* Hadley. BERMUDEZ, Cushman Lab. Foram. Res., Spec. Publ. 25, p. 259-260, pl. 18, figs. 31-33.

Our forms seem to belong to the same species as that reported from various Caribbean Tertiary localities. Bermudez gives a complete synonymy for this species in the above reference. The species was described from the Upper Oligocene (?) of Cuba, and since then has been reported from the Middle Tertiary of Jamaica, Haiti, Venezuela, and the Dominican Republic. Length of plesiotype, 0.48 mm; breadth, 0.36 mm; thickness, 0.22 mm. Specimens of almost twice these dimensions are found in the lower marine beds of the Louisiana Pleistocene.

VALVULINERIA MINUTA Parker
Pl. X, figs. 1, 2

1954. *Valvulineria minuta* PARKER, Harvard, Bull. Mus. Comp. Zool., vol. 111, no. 10, p. 527, pl. 9, figs. 4, 5, 6.

Our identification is verified by comparison with holotype and paratypes from the northeastern Gulf of Mexico. According to the above reference distribution in Recent sediments is at depths greater than 75 meters. Length of plesiotype, 0.18 mm; breadth, 0.14 mm.

VALVULINERIA PALMERAE Cushman and Todd
Pl. X, figs. 13, 28

1945. *Valvulineria palmerae* CUSHMAN and TODD, Cushman Lab. Foram. Res., Spec. Publ. 15, p. 56, pl. 8, fig. 18.
1951. *Valvulineria cf. araucana* (d'Orbigny). PHLEGER and PARKER, (not *Rosalina araucana* d'Orbigny, 1839), Geol. Soc. America, Mem. 46, pt. 2, p. 25, pl. 13, figs. 7a, b, 8a, b.
1954. *Valvulineria mexicana* PARKER, Harvard, Bull. Mus. Comp. Zool., vol. 111, no. 10, p. 526, pl. 9, figs. 1, 2, 3.

Identification is verified by comparison with topotypes from the Miocene Buff Bay Formation of Jamaica. Specimens from the Gulf of Mexico referred to *V. mexicana* Parker are within the range of variation of *V. palmerae*. The species has also been identified in the Upper Miocene (*Buccella mansfieldi* Zone) of offshore Louisiana. *V. palmerae* is very similar to *V. bradyana* (Fornasini) from the Pliocene of Italy but is smaller and has short umbilical processes which *V. bradyana* seems to lack. Distribution in Recent sediments is deeper than 75 meters. Length of plesiotype, 0.25 mm; breadth, 0.19 mm; thickness, 0.15 mm.

VULVULINA cf. V. DOMINICANA Bermudez
Pl. I, fig. 18

1949. *Vulvulina dominicana* BERMUDEZ, Cushman Lab. Foram. Res., Spec. Publ. 25, p. 55, pl. 1, figs. 54-57.

Our specimens are close to this Caribbean Miocene species. There is also a similarity to *V. dermouti* Boomgaart from the Miocene and Pliocene of Java. The Pleistocene specimens, however, are smaller than the holotypes of both of these species. To our knowledge this foraminifer has not been reported from the Gulf of Mexico. Length of figured specimen, 0.71 mm; breadth, 0.46 mm; thickness, 0.29 mm.

VIII. ILLUSTRATIONS

A. PHOTOGRAPHY

In this paper, the authors have followed the photographic techniques described by G. Fournier (1956) as closely as possible and, except for several drawings as noted in the explanation of plates, all illustrations are unretouched photographs.

The microscope used for photography was a Leitz monocular petrographic equipped with three periplanatic oculars 8X, 10X, and

12X, and four achromatic objectives, 3.2X, 10X, 25X, and 45X.

Pinhole diaphragms were constructed using the techniques described by Fournier (1950) of sizes 50 microns, 100 microns, 250 microns, 650 microns and 1000 microns. These diaphragms were fitted over the microscope objectives.

The lamps were Bausch and Lomb "Nicholas" illuminators equipped with blue filters. Most specimens required two or three such illuminators but smaller specimens necessitated a bank of four for adequate lighting.

The bellows assembly was a Kodak Precision Enlarger "A" equipped with a shutter inserted between the ocular and the film holder. A black felt tube connected the shutter to the bellows and the microscope.

The film holder permitted use of 2¼ x 3½ inch cut film. Kodak Panatomic "X" film was selected for this project.

Focusing was done on a ground glass cover placed at the top of the enlarger, and critical focusing was observed with a magnifying glass placed directly on the ground glass.

Specimens were mounted on a clean, clear glass slide by using a transparent, non-drying, gelatine-like glue called "Stay-Flat". This is a trade name for the substance which is primarily used in photographic work to hold large film sheets against the camera back.

A minute drop of "Stay-Flat" was put on the slide and allowed to dry for 10-15 minutes. The specimen was then placed on this material with a fine camel-hair brush and moved into the required position.

This technique allows the photographer to place a specimen in any desired position with ease. Specimens are easily removed with a brush.

Using this technique and equipment, and with an established routine, it was possible to produce an average of 8-10 negatives per hour.

Contact prints were made commercially, then cut out and mounted.

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PLATE DESCRIPTIONS

All figures are unretouched photographs unless otherwise noted. USNM numbers are from Foraminifera Catalog No. 130. For brevity, wells are designated as follows:

Well A California Company State Lease 2553 no. 1, South Pass Block 41, Offshore Plaquemines Parish, Louisiana
Well B California Company State Lease 1923 no. 1, Bay-T23S-R31E, Dixon Bay Field, Plaquemines Parish, Louisiana
Well C California Company P. O. D. no. 7, South Pass Block 24, Offshore Plaquemines Parish, Louisiana
Well D California Company State Lease 1278 no. 1-A, Main Pass Block 69 Field, Plaquemines Parish, Louisiana
Well E California Company U. S. A. no. 1, Burrwood Area, Block 83, Plaquemines Parish, Louisiana
Well F Phillips no. 1 State Bayou LeBoon, Sec. 48-T20S-R29E, Plaquemines Parish, Louisiana
Well G Humble Ellender no. 1, Sec. 23-T19S-R19E, Lirette Field, Terrebonne Parish, Louisiana
Well H Texas Co. Delta Duck Club, Unit 2, Well no. 1-A, Sec. 1-T21S-R19E, Plaquemines Parish, Louisiana
Well I Phillips no. 1 State Bastian Bay, Plaquemines Parish, Louisiana
Well J California Company State Lease 932, Well no. P-1, Block 26, Bay Marchand Field

Plate I

Figures		Page
1	*Cyclammina cancellata* H. B. Brady Side view of plesiotype from Well C, core 1875 ft. x17	32
2, 3	*Textularia conica* d'Orbigny Top and side views of plesiotype from Well A, core 578 ft. x42	55
4, 5	*Textularia candeiana* d'Orbigny Side and edge views of plesiotype from Well A, core 578 ft. x39	55
6	*Textularia mexicana* Cushman Side view of plesiotype from Well E, core 2777½ ft. x47	55
7	*Textularia* cf. *T. yaguatensis* Bermudez Side view of specimen from Well A, core 3560 ft. x55	55
8, 9	*Textularia sica* Lalicker and Bermudez Side and edge views of plesiotype from Well A, core 578 ft. x55	55
10, 11	*Textularia foliacea occidentalis* Cushman Side and edge views of plesiotype from Well C, core 1927 ft. x46	55
12	*Textularia mayori* Cushman Side view of plesiotype from Well A, core 610 ft. x25	55
13	*Siphotextularia affinis* (Fornasini) Side view of plesiotype from Well A, core 2580 ft. x47	54
14	*Siphotextularia rolshauseni* Phleger and Parker Side view drawing of plesiotype from Well A, core 578 ft. x90	54
15	*Bigenerina irregularis* Phleger and Parker Side view of plesiotype from Well A, core 578 ft. x55	23
16, 17	*Bigenerina textularioidea* (Goës) Side and edge views of plesiotypes from Well A, core 610 ft. Both x28	23
18	*Vulvulina* cf. *V. dominicana* Bermudez Side view of specimen from Well A, core 578 ft. x57	59
19	*Gaudryina aequa* Cushman Side view of plesiotype from Well A, core 578 ft. x69	35
20, 21	*Tritaxia mexicana* (Cushman) Side views of plesiotypes from Well C, core 1930 ft. 20, x31; 21, x37	57
22	*Alvarezina bradyi* (Cushman) Side view of plesiotype from Well C, core 1890 ft. x55	20
23	*Gaudryina (Pseudogaudryina) atlantica* (Bailey) Side view of plesiotype from Well C, core 1623 ft. x20	35
24, 25	*Neocuneolina angusta* (Cushman) Plesiotype from Well A, core 2418 ft. 24, apertural view; 25, edge view; both x24	44
26, 27	*Textulariella barrettii* (Jones and Parker) Edge and top views of plesiotype from Well D, drill cuttings 757-788 ft. x24	56

PLATE I

Plate II

Figures		Page
1, 2	*Alvarezina cyclostomata sinuata* Akers and Dorman, n. subsp. Side views of Holotype (USNM 641939) and paratype (USNM 641940) from Well H, core 2420 ft. 1, x29; 2, x37	21
3, 4	*Tritaxilina yasicaensis* Bermudez Side and top views of plesiotype from Well A, core 2418 ft. 3, x21; 4, x26	57
5, 6	*Liebusella soldanii* (Jones and Parker) Side views of plesiotype from Well A, core 2418 ft. 5, x14; 6, x21	42
7	*Sigmoilopsis subpoeyana* (Cushman) Side view of plesiotype from Well A, core 586 ft. x52	53
8	*Spiroloculina depressa* d'Orbigny Side view of plesiotype from Well A, core 3258 ft. x54	54
9, 10	*Sigmoilina distorta* Phleger and Parker Opposite sides of plesiotype from Well C, core 1930 ft. x52	53
11-13	*Quinqueloculina lamarckiana* d'Orbigny Top and opposite sides of plesiotype from Well A, core 3258 ft. x32	50
14, 15	*Massilina* sp. Opposite sides of specimen from Well F, drill cuttings 1840-1870 ft. x21	44
16-18	*Sigmoilopsis schlumbergeri* (A. Silvestri) Top and opposite sides of plesiotype from Well C, core 1890 ft. x24	53
19	*Quinqueloculina horrida* Cushman Side view of plesiotype from Well A, core 545 ft. x50	50
20	*Articulina auriculata* (Egger) Side view of plesiotype from Well A, core 586 ft. x55	22
21-23	*Quinqueloculina polygona* d'Orbigny Plesiotype from Well B, core 1154 ft. 21 and 23, opposite sides, x61. 22, edge view, x51	50
24-26	*Quinqueloculina agglutinans* d'Orbigny Top and opposite sides of plesiotype from Well F, drill cuttings 1325-1355 ft. x33	50
27-29	*Quinqueloculina bicostata* d'Orbigny Plesiotype from Well F, drill cuttings 1055-1085 ft. x32. 27 and 29, opposite sides. 28, top view.	50

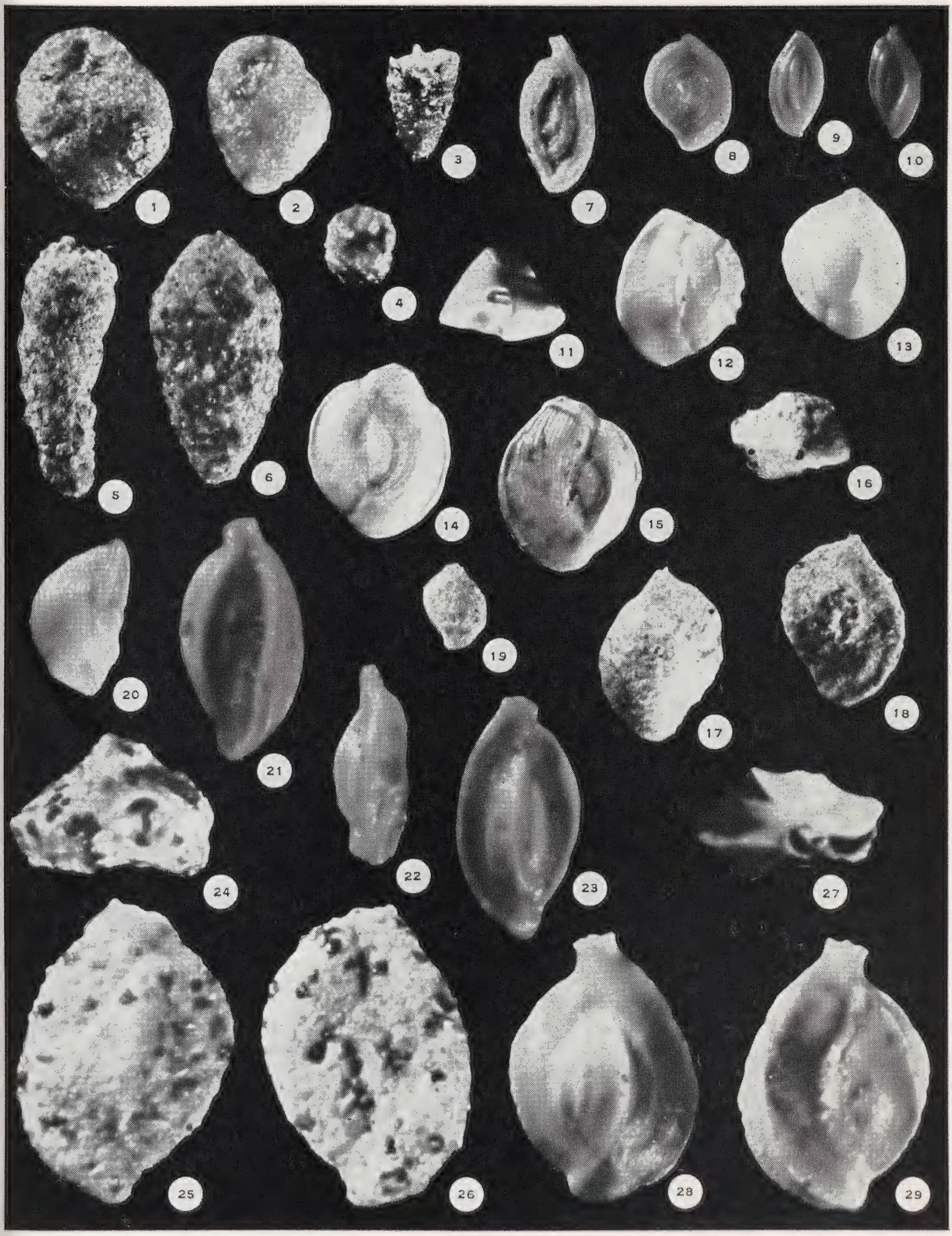
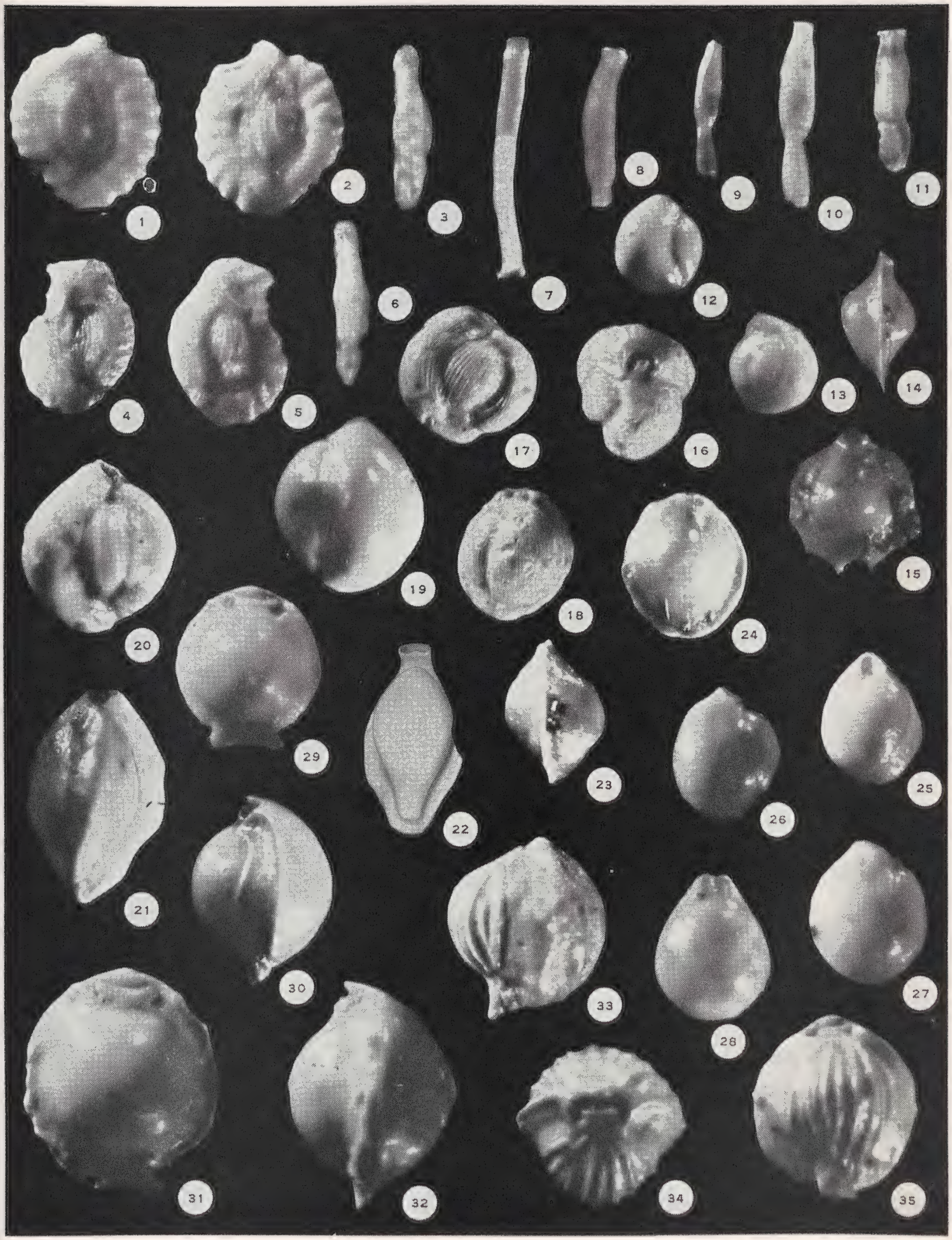


PLATE II

Plate III

Figures		Page
1-6	*Hauerina nacchara* Akers and Dorman, n. sp. 1-3, opposite sides and edge view of holotype (USNM 641941). 4-6, opposite sides and edge view of paratype (USNM 641942). Both from Well A, core 610 ft. All x61	38
7	*Tubinella* cf. *T. funalis* (H. B. Brady) Side view of specimen from Well A, core 610 ft. x62	58
8-10	*Articulina mayori* Cushman 8, side view of fragment, x73. 9 (x57) and 10 (x74), side views of another fragment. Both from Well A, core 610 ft.	22
11	*Articulina paucicostata* Cushman Side view of plesiotype from Well A, core 610 ft. x47	23
12, 13	*Triloculina circularis* Bornemann Opposite sides of plesiotype from Well C, core 1890 ft. x55	56
14, 15	*Pyrgo murrhina* (Schwager) Side and front views of plesiotype from Well C, core 1875 ft. x55	49
16-18	*Triloculina insignis* (H. B. Brady) Top, side, and edge views of plesiotype from Well D, drill cuttings 1518-1548 ft. x21	57
19, 20	*Triloculina trigonula* (Lamarck) Opposite sides of plesiotype from Well C, core 1890 ft. x39	57
21	*Triloculina tricarinata* d'Orbigny Side view of plesiotype from Well D, drilling cuttings 940-970 ft. x38	57
22	*Pyrgo nasutus* Cushman Front view drawing of plesiotype from Well A, core 531 ft. x125	49
23, 24	*Pyrgo* sp. "A" Side and front views of specimen from Well C, core 2070 ft. x37	50
25-28	*Biloculinella toddae* Andersen 25, 26, front and side views of plesiotype from Well C, core 1890 ft. x63. 27, 28, opposite sides of another plesiotype from Well C, core 1890 ft. x62	23
29-32	*Pyrgo vespertilio* (Schlumberger) 29, 30, front and side views of plesiotype from Well D, core 1103 ft. x51. 31, 32, front and side views of plesiotype from Well A, core 2418 ft. x48	49
33-35	*Pyrgo* sp. "B" Side, top, and front views of specimen from Well D, drill cuttings 940-970 ft. x41	50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25
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29
30
31
32
33
34
35

PLATE III

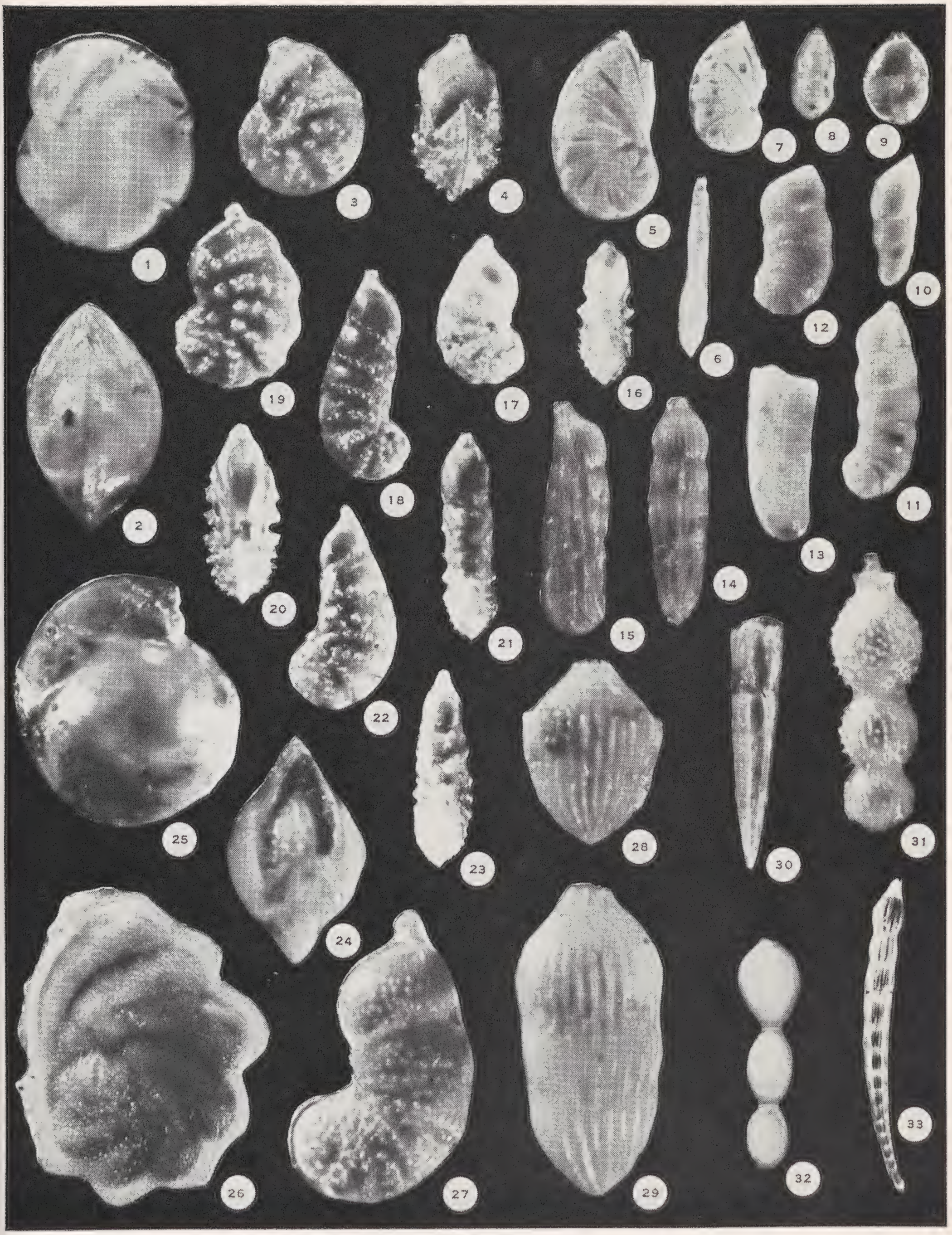
Plate IV

Figures		Page
1, 2	*Pyrgo comata* (H. B. Brady) Side and front views of plesiotype from Well D, drill cuttings 1334-1364 ft. x20	49
3	*Nodobaculariella atlantica* Cushman and Hanzawa Side view of plesiotype from Well D, drill cuttings 1091-1121 ft. x32	45
4	*Nodobaculariella cassis* (d'Orbigny) Side view of plesiotype from Well A, core 592 ft. x32	45
5	*Cyclogyra planorbis* (Schultze) Side view of plesiotype from Well A, core 592 ft. x67	32
6, 7	*Marginulinopsis senni lacrimata* Akers and Dorman, n. subsp. Face and side views of holotype (USNM 641943) from Well B, core 2916 ft. x22	44
8	*Lenticulina calcar* (Linné) Side view drawing of plesiotype from Well C, core 1830 ft. x66	41
9, 10	*Lenticulina* cf. *L. Arcuato-striata* (Hantken) Side and face views of specimen from Well A, core 578 ft. 9, x45. 10, x49	40
11, 12	*Pyrgo carinata* (d'Orbigny) Front and side views of plesiotype from Well A, core 610 ft. x57	49
13, 14	*Lenticulina atlantica* (Barker) Side and face views of plesiotype from Well A, core 610 ft. x39	40
15, 16	*Lenticulina melvilli* (Cushman and Renz) Face and side views of plesiotype from Well A, core 3490 ft. x39	41
17, 18	*Lenticulina occidentalis* (Cushman) Side and face views of plesiotype from Well A, core 3258 ft. x39	41
19, 20	*Lenticulina orbicularis* (d'Orbigny) Face and side views of plesiotype from Well A, core 3300 ft. x45	41
21	*Lenticulina cultrata* (Montfort) Side view of plesiotype from Well C, core 1890 ft. x17	41
22-26	*Lenticulina bowdenensis* (Cushman) 22, 24, 25, 26, side views of plesiotypes from Well D, drill cuttings 1181-1212 ft. 23, face view of 22. 22, x23; 23, x22; 24, x15; 25, x18; 26, x24	40

PLATE IV

Plate V

Figures		Page
1, 2	*Lenticulina* sp. "B" Side and face views of specimen from Well A, core 3490 ft. 1, x47. 2, x50	42
3, 4	*Lenticulina* sp. "A" Side and face views of specimen from Well A, core 3520 ft. x25	42
5-7	*Planularia quasitrinae* Akers and Dorman, n. sp. 5, 6, side and face views of holotype (USNM 641944), x23. 7, side view of paratype (USNM 641945), x22. Both from Well B, core 2916 ft.	47
8, 9	*Lenticulina peregrina* (Schwager) Face and side views of plesiotype from Well B, core 1880 ft. x49	41
10	*Marginulina glabra* d'Orbigny Side view of plesiotype from Well A, core 545 ft. x58	43
11, 12	*Marginulina basispinosa* Cushman and Renz Side views of plesiotypes from Well D, drill cuttings 2403-2829 ft. x22	42
13	*Marginulina sublituus multicamerata* Cushman and Stainforth Side view of plesiotype from Well A, core 3490 ft. x57	43
14, 15	*Marginulina* cf. *M. costata coarctata* Silvestri Edge and side views of specimen from Well B, core 1885 ft. x21	43
16-23	*Marginulina subaculeata glabrata* (Cushman) 17, 18, 19, 22, side views of four plesiotypes and 16, 21, 20, 23, edge views of these specimens. All from Well C, core 1875 ft. All x20	43
24, 25	*Lenticulina rotulata* (Lamarck) Face and side views of plesiotype from Well C, core 1890 ft. 24, x40. 25, x45	42
26	*Lenticulina* sp. "C" Side view of specimen from Well D, drill cuttings 512-543 ft. x14	42
27	*Marginulinopsis marginulinoides* (Goës) Side view of plesiotype from Well A, core 3430 ft. x46	43
28, 29	*Pseudonodosaria comatula* (Cushman) 28, side view of plesiotype, x65. 29, side view of another plesiotype, x61. Both from Well A, core 3300 ft.	48
30	*Nodosaria fusta* Cushman and Todd Side view of plesiotype from Well C, core 1930 ft. x20	45
31	*Nodosaria hispida* d'Orbigny .Side view of plesiotype from Well C, core 1830 ft. x70	46
32	*Dentalina* cf. *D. dispar* Reuss Side view drawing of specimen from Well A, core 3520 ft. x160	32
33	*Dentalina vertebralis albatrossi* (Cushman) Side view of plesiotype from Well C, core 1982 ft. x11	32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26
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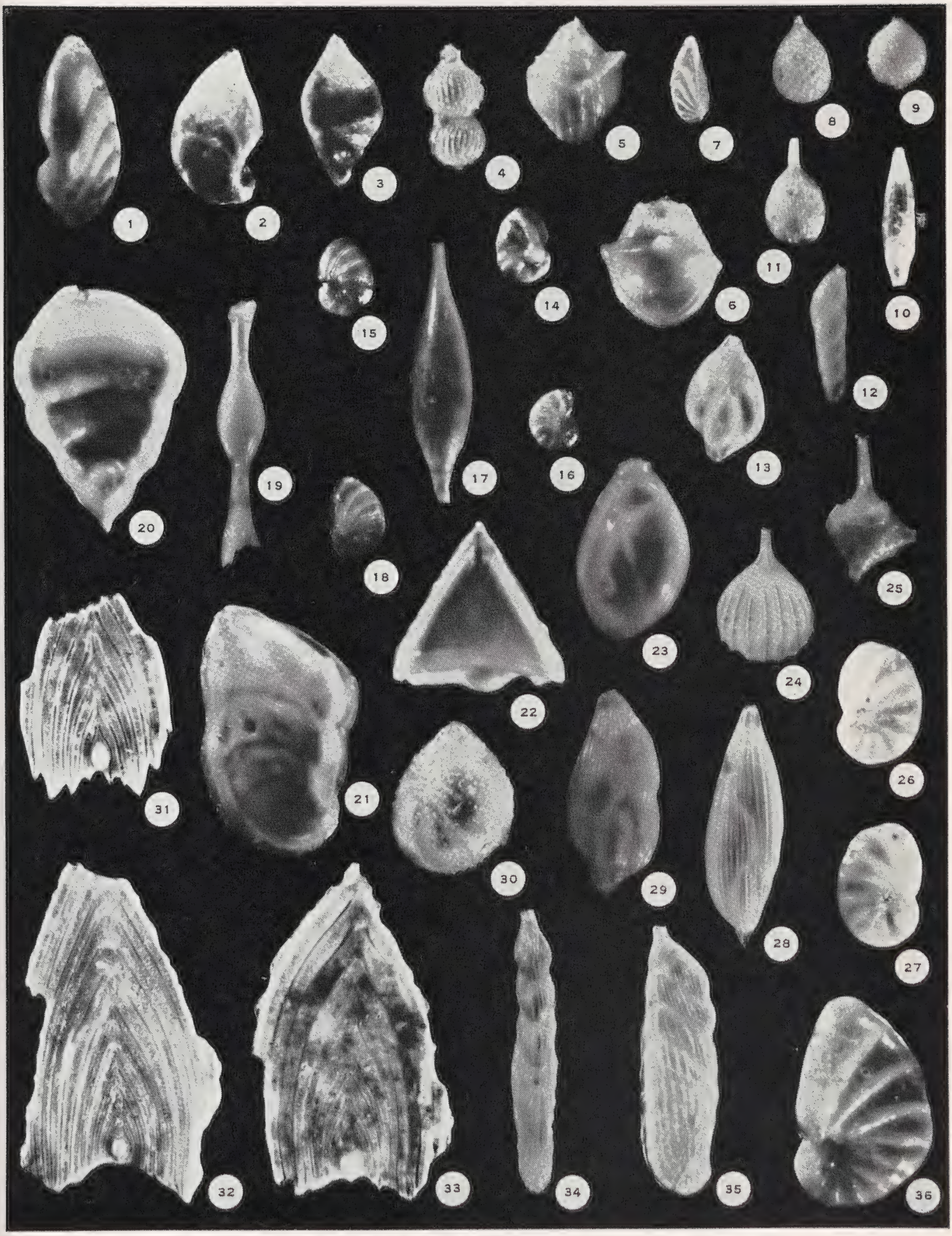
28
29
30
31
32
33

PLATE V

Plate VI

Figures		Page
1	*Saracenaria* sp. "B" Side view of specimen from Well A, core 578 ft. x42	52
2, 3	*Saracenaria* sp. "A" Side and face views of specimen from Well A, core 3430 ft. x55	52
4	*Amphicoryna cf. A. intercellularis* (H. B. Brady) Side view of specimen from Well A, core 3300 ft. x50	21
5, 6	*Lingulina* sp. Edge and side views of specimen from Well A, core 3300 ft. x40	42
7	*Saracenaria* sp. "C" Side view of specimen from Well A, core 3104 ft. x50	52
8	*Oolina hexagona* (Williamson) Side view of plesiotype from Well A, core 578 ft. x65	46
9	*Lagena* cf. *L. hispida* Reuss Side view of specimen from Well A, core 3574 ft. x53	40
10	*Lagena gracillima mollis* Cushman Side view of plesiotype from Well A, core 3104 ft. x72	39
11	*Lagena striata* (d'Orbigny) Side view of plesiotype from Well A, core 3560 ft. x58	40
12	*Dentalina communis* d'Orbigny Side view of plesiotype from Well A, core 3560 ft. x45	32
13	*Guttulina* sp. Side view of specimen from Well A, core 545 ft. x53	36
14, 15	*Nonionella basiloba* Cushman and McCulloch Opposite sides of plesiotype from Well A, core 1100 ft. x52	46
16	*Melonis pompilioides* (Fichtel and Moll) Side view of plesiotype from Well A, core 3258 ft. x46	44
17	*Lagena gracillima* (Seguenza) Side view of plesiotype from Well C, core 1890 ft. x125	39
18	*Nonionella* sp. Side view of specimen from Well A, core 3520 ft. x47	46
19	*Nodosaria pyrula* d'Orbigny Side view of plesiotype from Well A, core 578 ft. x51	46
20-22	*Saracenaria italica* Defrance Face, side, and top views of plesiotype from Well A, core 1880 ft. x25	52
23	*Globulina* sp. Side view of specimen from Well A, 592 ft. x70	36
24	*Lagena sulcata spicata* Cushman and McCulloch Side view drawing of plesiotype from Well A, core 3560 ft. x95	40
25	*Ramulina globulifera* H. B. Brady Side view of plesiotype from Well C, core 1890 ft. x62	51
26, 27	*Florilus atlanticus* (Cushman) Opposite sides of plesiotype from Well A, core 578 ft. x40	34
28	*Guttulina australis* (d'Orbigny) Side view of plesiotype from Well A, core 592 ft. x65	36
29	*Guttulina pulchella* d'Orbigny Side view of plesiotype from Well A, core 610 ft. x48	36
30	*Globulina caribaea* d'Orbigny Side view of plesiotype from Well A, core 2418 ft. x55	36
31-33	*Frondicularia sagittula* Vanden Broeck Three megalospheric plesiotypes from Well D, drill cuttings 1151-1181 ft. 31, x14; 32, x12; 33, x9	34
34, 35	*Vaginulinopsis planata* (Phleger and Parker) Edge and side views of plesiotype from a mudlump at the mouth of Southwest Pass in the Mississippi River delta. x14	59
36	*Florilus grateloupi* (d'Orbigny) Side view of plesiotype from Well A, core 610 ft. x54	34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32
33
34
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36

PLATE VI

Plate VII

Figures		Page
1, 2	*Peneroplis proteus* d'Orbigny Side views of two plesiotype from Well A, core 592 ft. 1, x33. 2, x47	47
3	*Globobulimina mississippiensis* Parker Side view of plesiotype from Well A, core 545 ft. x45	36
4-7	*Buliminella* cf. *B. bassendorfensis* Cushman and Parker Side views of four specimens from Well A. 4, x59; 5, x58; 6, x58; from core 3520 ft. 7, x65; from core 1100 ft.	29
8, 9	*Fissurina* sp. "C" Edge and side views of specimen from Well C, core 1830 ft. x45	33
10	*Fissurina* sp. "B" Side view of specimen from Well A, core 3560 ft. x53	33
11, 12	*Fissurina* sp. "D" Edge and side views of specimen from Well C, core 1830 ft. x57	33
13	*Globobulimina affinis* (d'Orbigny) Side view of plesiotype from Well A, core 3430 ft. x42	35
14, 39	*Bulimina marginata* d'Orbigny Side views of two plesiotypes from Well A. 14, core 3104 ft. x61. 39, core 3490 ft. x72	28
15	*Bulimina striata mexicana* Cushman Side view of plesiotype from Well A, core 3104 ft. x59	29
16, 17	*Elphidium discoidale* (d'Orbigny) Face and side views of plesiotype from Well A, core 2418 ft. x39	32
18	*Sorites marginalis* (Lamarck) Side view of plesiotype from Well I, drill cuttings 1325-1355 ft. x24	54
19, 20	*Fissurina* sp. "A" Edge and side view drawings of specimen from Well A, core 578 ft. x106	33
21	*Fursenkoina* cf. *F. bradyi* (Cushman) Side view of specimen from Well A, core 3490 ft. x49	34
22	*Bulimina spicata* Phleger and Parker Side view drawing of plesiotype from Well A, core 2367 ft. x160	29
23, 24	*Plectofrondicularia floridana* Cushman Edge and side views of plesiotype from Well A, core 3460 ft .x49	48
25	*Turrilina* sp. Side view drawing of specimen from Well A, core 578 ft. x127	58
26, 27	*Elphidium sagrum* (d'Orbigny) Face and side views of plesiotype from Well A, core 610 ft. x55	33
28, 29	*Elphidium fimbriatulum* (Cushman) Side and face views of plesiotype from Well A, core 578 ft. x62	32
30	*Archaias angulatus* (Fichtel and Moll) Side view of plesiotype from Well A, core 592 ft. x28	22
31, 32	*Elphidium poeyanum* (d'Orbigny) Face and side views of plesiotype from Well A, core 578 ft. x52	33
33	*Bulimina aculeata* d'Orbigny Side view of plesiotype from Well A, core 3490 ft. x68	28
34	*Fursenkoina schreibersiana* (Czjzek) Side view of plesiotype from Well C, core 1830 ft. x42	35
35	*Fursenkoina mexicana* (Cushman) Side view of plesiotype from Well A, core 592 ft. x57	35
36	*Buliminella elegantissima* (d'Orbigny) Side view drawing of plesiotype from Well A, core 3590 ft. x187	29
37	*Bulimina alazanensis spatiosa* Cushman and Todd Side view of plesiotype from Well C, core 1830 ft. x37	28
38	*Bulimina patagonica* d'Orbigny Side view drawing of plesiotype from Well A, core 545 ft. x172	28

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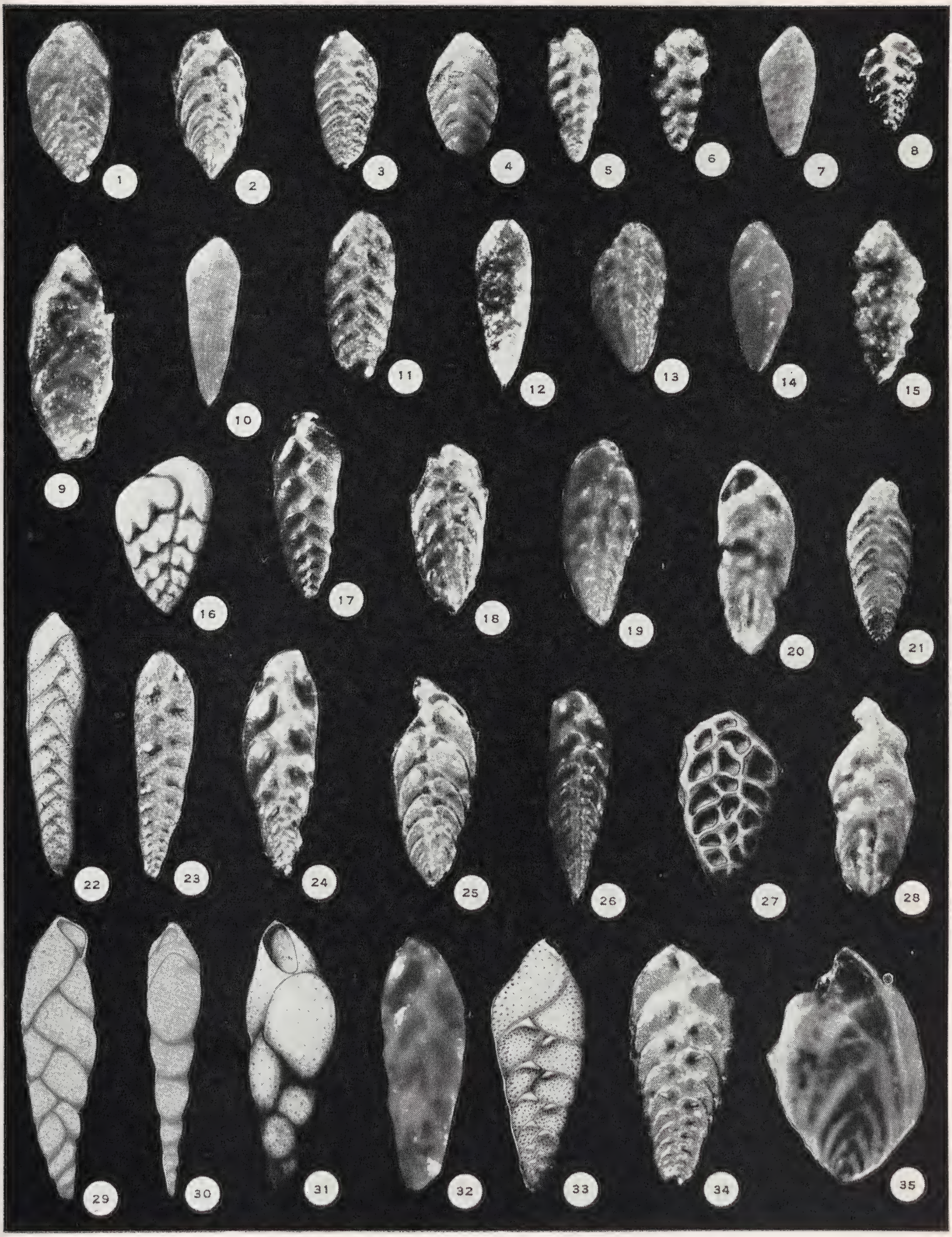
36
37
38
39

PLATE VII

Plate VIII

Figures		Page
1	*Bolivina goësii* Cushman Side view of plesiotype from Well A, core 3258 ft. x59	25
2, 18, 25	*Bolivina subaenariensis lucida* Akers and Dorman, n. subsp. 2, Side view of paratype (USNM 641947), x52. 18, Side view of paratype (USNM 641948, x48. 25, Side view of holotype (USNM 641946), x 51. All from Well A, core 3300 ft.	26
3, 21	*Bolivina catanensis* Seguenza Side views of two plesiotypes from Well A, core 3104 ft. 3, x86; 21, x91	24
4	*Bolivina ordinaria* Phleger and Parker Side view of plesiotype from Well A, core 3258 ft. x83	25
5	*Bolivina lowmani* Phleger and Parker Side view of plesiotype from Well A, core 2238 ft. x90	25
6, 15	*Bolivina subspinescens* Cushman Side views of two plesiotypes from Well A, both, x86. 6, core 3258 ft. 15, core 2418 ft.	27
7	*Bolivina albatrossi* Cushman Side view of plesiotype from Well A, core 3104 ft. x56	24
8	*Bolivina difformis* (Williamson) Side view of plesiotype from Well A, core 545 ft. x80	24
9	*Bolivina* cf. *B. striatula* Cushman Side view of specimen from Well A, core 578 ft. x82	26
10	*Bolivina spinata* Cushman Side view of plesiotype from Well A, core 545 ft. x55	26
11	*Bolivina minima* Phleger and Parker Side view of homeotype from Well A, core 3300 ft. x88	25
12	*Bolivina hastata* Phleger and Parker Side view of plesiotype from Well A, core 3258 ft. x82	25
13, 19	*Bolivina subaenariensis mexicana* Cushman Side views of two plesiotypes from Well A, core 3104 ft. 13, x55; 19, x58	27
14, 26	*Bolivina fragilis* Phleger and Parker 14, Side view of megalospheric plesiotype from Well A, core 2238 ft. x55. 26, Side view of microspheric plesiotype from Well A, core 1100 ft. x56	25
16	*Bolivina plicatella* Cushman Side view drawing of plesiotype from Well A, core 3258 ft. x126	26
17	*Bolivina pacifica* Cushman and McCulloch Side view of plesiotype from Well A, core 1270 ft. x90	25
20, 28	*Bolivina subaenariensis* Cushman Side views of two plesiotypes from Well A, core 3490 ft. 20, x59; 28, x57	26
22	*Bolivina daggarius* Parker Side view drawing of plesiotype from Well A, core 3104 ft. x154	24
23	*Bolivina acerosa* Cushman Side view of plesiotype from Well A, core 2580 ft. x86	23
24	*Bolivina alata* (Seguenza) Side view of plesiotype from Well A, core 3104 ft. x82	24
27	*Bolivina thalmanni* Renz Side view drawing of plesiotype from Well A, core 3560 ft. x70	27
29, 30	*Fursenkoina finissima* Akers and Dorman, n. sp. Side and edge view drawings of holotype (USNM 641949) from Well A, core 1270 ft. 29, x173; 30, x166	34
31	*Fursenkoina complanata* (Egger) Side view drawing of plesiotype from Well A, core 1436 ft. x141	34
32	*Fursenkoina pontoni* (Cushman) Side view of plesiotype from Well A, core 3490 ft. x57	35
33	*Bolivina translucens* Phleger and Parker Side view drawing of plesiotype from Well A, core 1436 ft. x187	28
34	*Bolivina barbata* Phleger and Parker Side view of plesiotype from Well A, core 1100 ft. x90	24
35	*Bolivina* cf. *B. subtenuis* Cushman Side view of specimen from Well A, core 610 ft. x86	27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32
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34
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PLATE VIII

Plate IX

Figures		Page
1	*Uvigerina bellula* Bandy Side view drawing of plesiotype from Well A, core 3258 ft. x67	58
2-5	*Trimosina denticulata* Akers and Dorman, n. sp. 2, 4, opposite sides of holotype (USNM 641950), x55. 3, Side view of paratype (USNM 641952), x 52. 5, Side view of paratype (USNM 641951), x54. All from Well A, core 3460 ft.	57
6, 7	*Rosalina floridana* (Cushman) Opposite sides of plesiotype from Well A, core 1830 ft. x50	51
8-10	*Sagrina pulchella* d'Orbigny 8, Side view of plesiotype, x58. 9, 10, Side and edge view drawings of small, slender specimen, x135. Both from Well A, core 610 ft.	52
11	*Nodosaria gracillima* (Cushman and Jarvis) Side view of plesiotype from Well A, core 3258 ft. x55	45
12, 13	*Rosalina concinna* (H. B. Brady) Drawings of opposite sides of an incomplete specimen from Well A, core 592 ft. x68	51
14, 15	*Rosalina bulbosa* (Parker) Drawings of opposite sides of two plesiotypes from Well A, core 586 ft. Both x65	51
16-18	*Trifarina holcki* Akers and Dorman, n. sp. 16, Side view of paratype (USNM 641954), x61. 17, Side view of holotype (USNM 641953), x58. 18, Side view of paratype (USNM 641955), x67. All from Well A, core 3560 ft.	56
19	*Trifarina eximia* (Cushman and Jarvis) Side view drawing of plesiotype from Well A, core 2418 ft. x57	56
20	*Chrysalidinella* sp. Side view drawing of specimen from Well A, core 578 ft. x82	30
21	*Spirillina vivipara* Ehrenberg Side view drawing of plesiotype from Well A, core 592 ft. x89	54
22	*Rectobolivina advena* (Cushman) Side view of homeotype from Well A, core 578 ft. x57	51
23, 24	*Rosalina* cf. *R. nitida* (Williamson) Opposite sides of specimen from Well A, core 610 ft. x49	52
25	*Siphogenerina raphanus* (Parker and Jones) Side view of plesiotype from Well B, core 2916 ft. x43	53
26	*Uvigerina peregrina* Cushman Side view of plesiotype from Well A, core 3300 ft. x47	58
27, 28, 35	*Reussella miocenica* Cushman Side views of three plesiotypes from Well A, core 578 ft. 27, drawing, x41. 28, x80. 35, x90	51
29	*Uvigerina flintii* Cushman Side view of homeotype from Well E, core 2777½ ft. x60	58
30	*Pavonina atlantica* Cushman Side view of plesiotype from Well A, core 578 ft. x54	47
31	*Uvigerina peregrina parvula* Cushman Side view of plesiotype from Well A, core 3258 ft. x69	58
32	*Trifarina bella* (Phleger and Parker) Side view drawing of plesiotype from Well A, core 586 ft. x86	56
33	*Reussella minuta* Drooger and Kaasschieter Side view of plesiotype from Well A, core 2418 ft. x72	51
34	*Siphonodosaria antillea* (Cushman) Side view of plesiotype from Well A, core 3258 ft. x45	53
36, 37	*Rosalina floridensis* (Cushman) Opposite sides of plesiotype from Well A, core 578 ft. x44	52
38	*Uvigerina peregrina bradyana* Cushman Side view of plesiotype from Well A, core 1100 ft. x124	58
39	*Siphonodosaria verneuili* (d'Orbigny) Side view of incomplete specimen from Well A, core 3300 ft. x55	53

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37
38
39

PLATE IX

Plate X

Figures		Page
1, 2	*Valvulineria minuta* Parker Opposite sides (drawings) of plesiotype from Well A, core 3258 ft. x93	59
3, 4	*Buccella hannai* (Phleger and Parker) Opposite sides of plesiotype from Well A, core 592 ft. x50	28
5, 6	*Neoeponides turgidus* (Phleger and Parker) Opposite sides (drawings) of plesiotype from Well A, core 3104 ft. x105	45
7, 8	*Gyroidinoides regularis* (Phleger and Parker) Opposite sides of plesiotype from Well A, core 3104 ft. x50	37
9, 10	*Neoeponides tumidulus* (H. B. Brady) Opposite sides (drawings) of plesiotype from Well A, core 3104 ft. x94	45
11, 12	*Neoeponides coryelli* (Palmer) Opposite sides of plesiotype from Well A, core 2418 ft. x18	44
13, 28	*Valvulineria palmerae* Cushman and Todd Spiral and umbilical sides of plesiotype from Well A, core 3460 ft. 13, x61. 28, x74	59
14, 15	*Ammonia beccarii* (Linné) variants Opposite sides of specimen from Well A, core 545 ft. x44	21
16, 17	*Valvulineria herricki* (Hadley) Opposite sides of plesiotype from Well A, core 3574 ft. x47	59
18, 19	*Hyalinea balthica* (Schroeter) 18, Side view of microspheric plesiotype. 19, Side view of megalospheric plesiotype. Both, x47, and both from Well A, core 3300 ft.	38
20, 21	*Gyroidinoides neosoldanii* (Brotzen) Opposite sides of plesiotype from Well A, core 1436 ft. x51	36
22, 23	*"Rotalia" translucens* Phleger and Parker Opposite sides of plesiotype from Well A, core 2418 ft. x50	52
24, 25	*Rosalina* cf. *R. suezensis* (Said) Opposite sides (drawings) of specimen from Well A, core 586 ft. x97	52
26, 27	*Eponidella gardenislandensis* Akers Opposite sides (drawings) of heautotype from Well A, core 711 ft. x157	33
29, 30	*Buccella* sp. Opposite sides (drawings) of specimen from Well A, core 2418 ft. x80	28
31, 32	*Gyroidinoides orbicularis* (d'Orbigny) Opposite sides of plesiotype from Well A, core 3258 ft. x63	36
33-35	*Gyroidinoides soldanii altiformis* (R. E. and K. C. Stewart) Edge view and opposite sides of plesiotype from Well A, core 3258 ft. x45	37
36, 37	*Oridorsalis umbonatus ecuadorensis* (Galloway and Morrey) Opposite sides of plesiotype from Well A, core 578 ft. x93	46
38, 39	*Neoeponides parantillarum* (Galloway and Heminway) Opposite sides of plesiotype from Well A, core 2418 ft. x56	44

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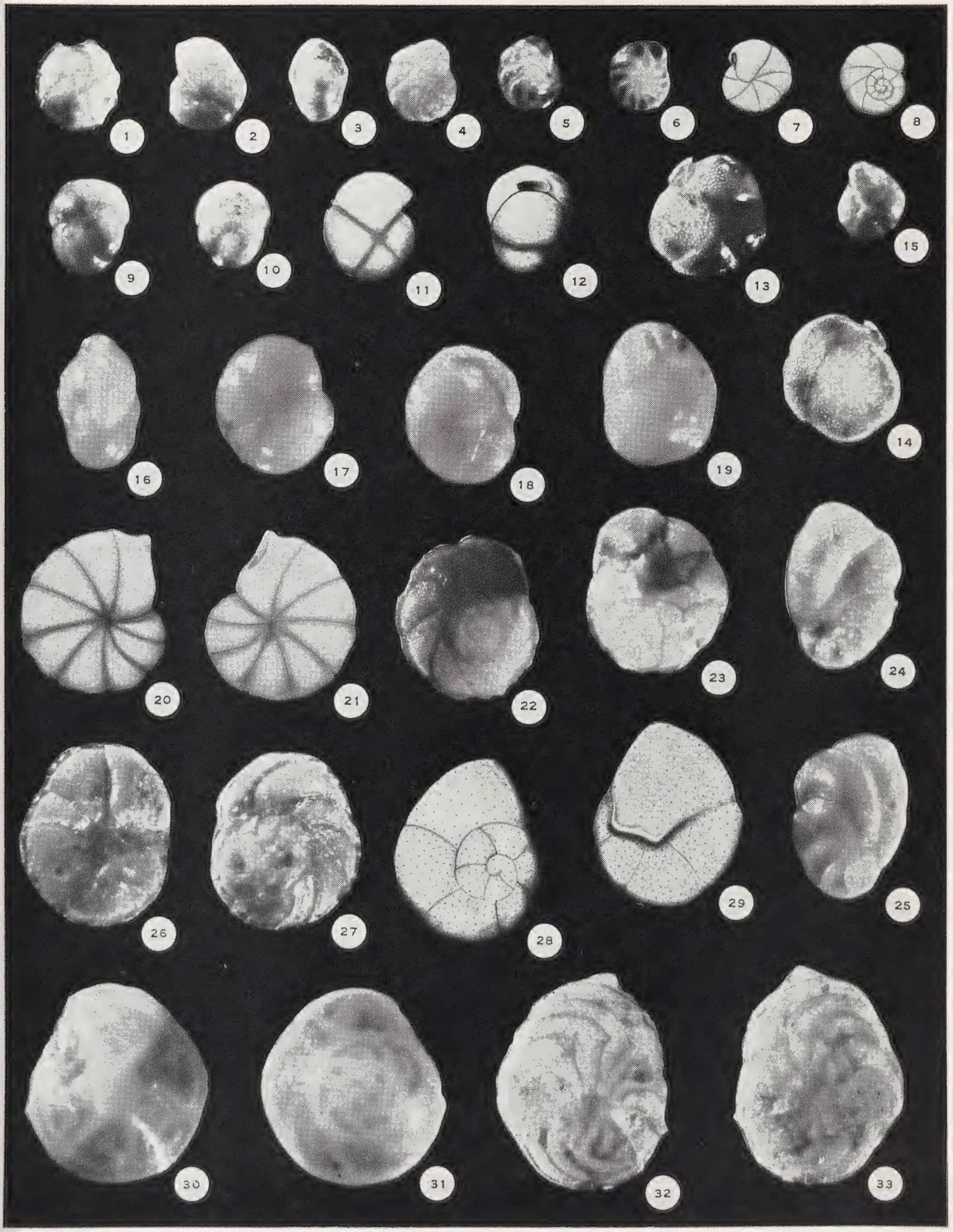
PLATE X

Plate XI

Figures		Page
1	*Cassidulina neocarinata* Thalmann Side view of plesiotype from Well A, core 3574 ft. x53	30
2	*Pullenia* sp. Side view of specimen from Well B, core 1885 ft. x60	49
3, 15	*Pullenia quinqueloba* (Reuss) Face and side views of plesiotype from Well A, core 3460 ft. x51	49
4	*Cassidulina laevigata* d'Orbigny Side view of plesiotype from Well A, core 3300 ft. x54	30
5	*Cassidulina curvata* Phleger and Parker Side view of plesiotype from Well A, core 3258 ft. x49	29
6	*Cassidulina norcrossi australis* Phleger and Parker Side view of plesiotype from Well A, core 3104 ft. x51	30
7, 8	*Epistominella vitrea* Parker Opposite sides (drawings) of plesiotype from Well A, core 545 ft. x38	33
9, 10	*Sphaeroidina bulloides* d'Orbigny Opposite sides of plesiotype from Well A, core 2367 ft. 9, x42; 10, x38	54
11, 12	*Pullenia bulloides* (d'Orbigny) Side and face views (drawings) of plesiotype from Well B, core 1880 ft. x58	49
13, 14	*Siphonina pulchra* Cushman Opposite sides of plesiotype from Well A, core 2580 ft. x43	53
16-18	*Islandiella crassa* (d'Orbigny) Edge and opposite sides of plesiotype from Well A, core 3104 ft. x64	39
19	*Islandiella subglobosa* (H. B. Brady) Side view of plesiotype from Well A, core 3560 ft. x56	39
20, 21	*Stetsonia minuta* Parker Opposite sides (drawings) of plesiotype from Well A, core 578 ft. x240	55
22, 23	*Asterigerina carinata* d'Orbigny Opposite sides of plesiotype from Well A, core 592 ft. x33	23
24, 25	*Cancris sagra* (d'Orbigny) Opposite sides of plesiotype from Well A, core 578 ft. x56	29
26, 27	*Poroeponides cribrorepandus* Asano and Uchio Opposite sides of plesiotype from Well A, core 578 ft. x39	48
28, 29	*Quadrimorphina vilardeboana glabra* (Cushman) Opposite sides (drawings) of plesiotype from Well C, core 1890 ft. x125	50
30, 31	*Hoeglundina elegans* (d'Orbigny) Opposite sides of plesiotype from Well C, core 1890 ft. x55	38
32, 33	*Amphistegina lessonii* d'Orbigny Opposite sides of plesiotype from Well B, core 2916 ft. x35	21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20
21
22
23
24
26
27
28
29
25
30
31
32
33

PLATE XI

Plate XII

Figures — Page

1, 2 — *Pulleniatina obliquiloculata* (Parker and Jones) 20
Opposite sides of plesiotype from Well C, core 1927 ft. x55

3-5 — *Globigerina altispira altispira* Cushman and Jarvis 14
3, spiral view of plesiotype, x59. 4, 5, spiral and umbilical views of another plesiotype, x61. Both from Well G, core 2570 ft.

6-8 — *Globigerina eggeri* Rhumbler 15
Spiral, edge, and umbilical views of plesiotype from Well A, core 3430 ft. x67

9, 10 — *Globigerina conglobata* H. B. Brady 15
Opposite sides of plesiotype from Well A, core 3520 ft. x60

11, 12 — *Globigerina rubra* d'Orbigny 17
Umbilical views of two plesiotypes from Well A, core 3560 ft. 11, x73. 12, x75

13-15 — *Globorotalia menardii menardii* (d'Orbigny) 18
Spiral, umbilical, and edge views of plesiotype from Well C, core 1610 ft. x69

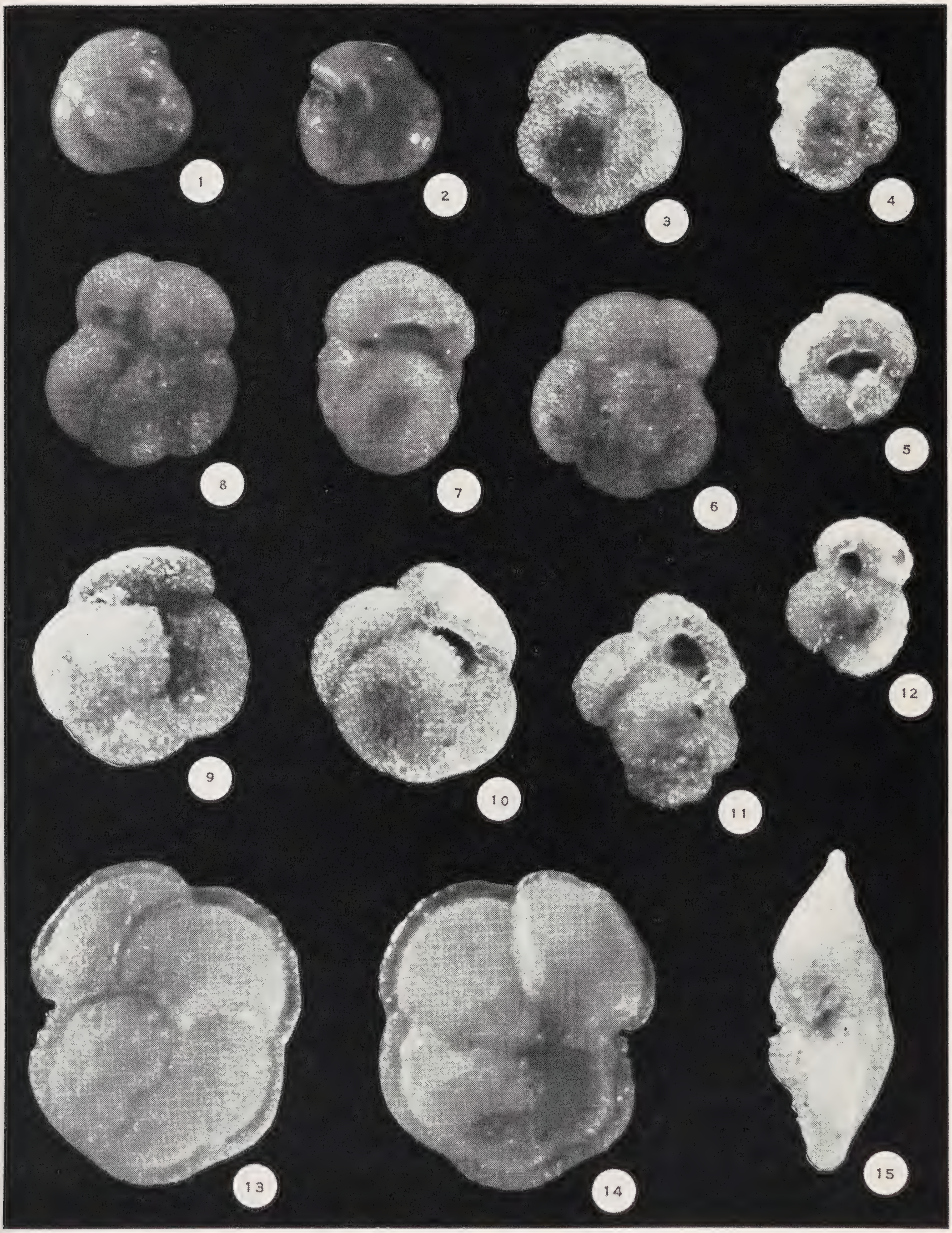

PLATE XII

Plate XIII

Figures		Page
1, 2	*Globigerina aequilateralis* H. B. Brady Opposite sides of plesiotype from Well A, core 3574 ft. x57	13
3, 4, 10	*Globigerina glutinata* Egger 3, 4, opposite sides (drawings) of plesiotype from Well A, core 3430 ft. x100. 10, umbilical view of plesiotype from Well A, core 3430 ft. x61	15
5	*Globigerina parkerae* (Loeblich and Tappan) Umbilical view of plesiotype from Well A, core 3104 ft. x71	16
6	*Globigerina* cf. *G. pachyderma* (Ehrenberg) Umbilical view of specimen from Well A, core 3300 ft. x63	16
7	*Globigerina universa* (d'Orbigny) Specimen from Well A, core 3104 ft. x39	17
8, 9	*Globigerina bradyi* Wiesner Spiral and edge views (drawings) of plesiotype from Well A, core 3300 ft. x107	14
11, 12	*Globigerina bulloides* d'Orbigny 11, umbilical view of plesiotype, x70. 12, spiral view of another plesiotype, x71. Both from Well A, core 3560 ft.	14
13, 14	*Sphaeroidinella dehiscens* (Parker and Jones) Umbilical views of two plesiotypes from Well A, core 3560 ft. 13, x46. 14, x44	20
15, 16	*Globigerina triloba* Reuss Side and umbilical views of plesiotype from Well A, core 3430 ft. x68	17
17-19	*Globigerina inflata* d'Orbigny Three different views of plesiotype from Well A, core 3258 ft. x69	16
20-22	*Globorotalia punctulata* (d'Orbigny) Side, umbilical, and spiral views of plesiotype from Well A, core 3104 ft. 20, x63. 21, x67. 22, x70	19

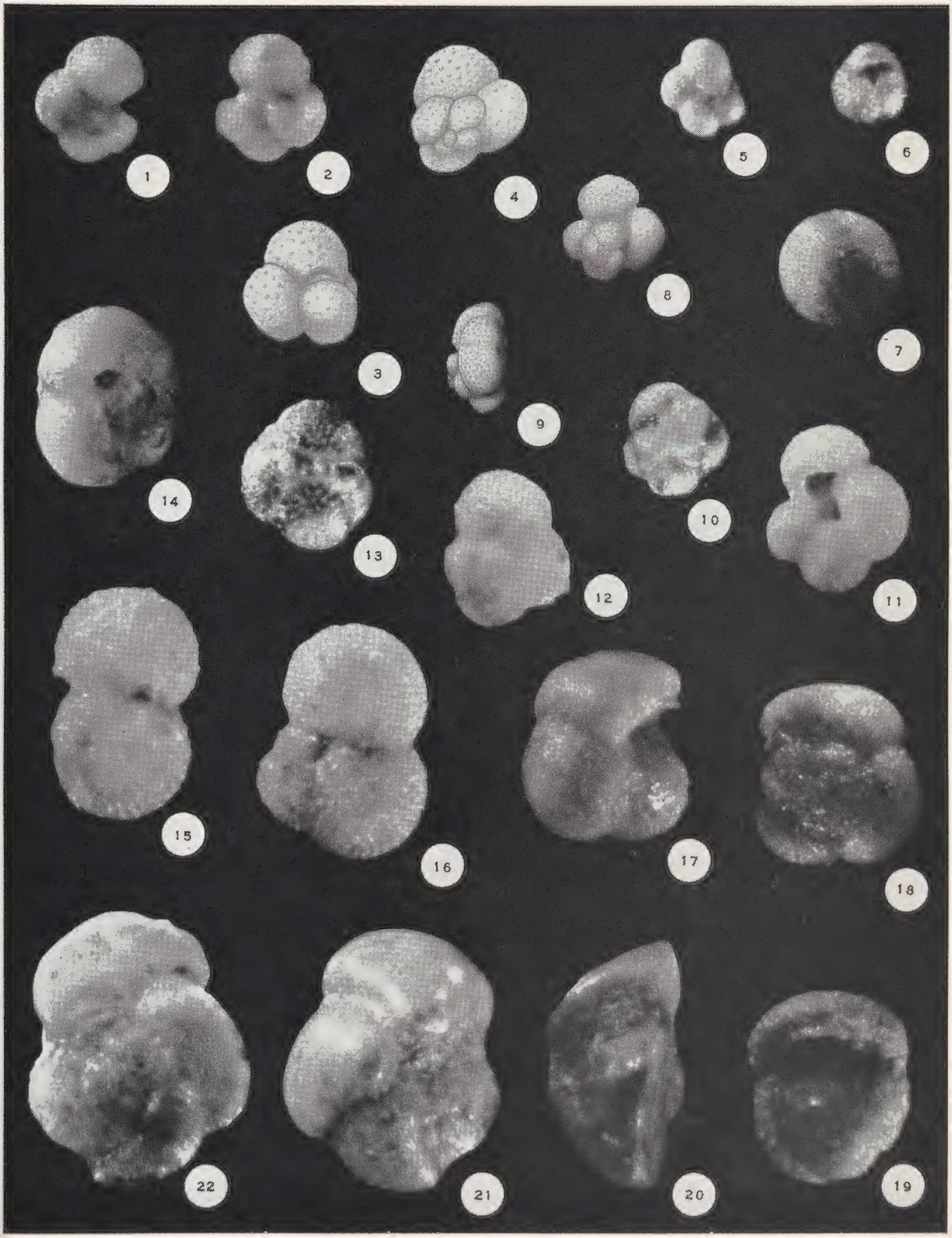

PLATE XIII

Plate XIV

Figures		Page
1-5, 19-21	*Globorotalia menardii miocenica* D. K. Palmer 1, 2, spiral and umbilical views of plesiotype from Well A, core 3560 ft. x60. 3-5, spiral, umbilical, and edge views of another plesiotype from Well A, core 3560 ft. 3, x66; 4, 5, x60. 19-21, spiral, umbilical, and edge views of a plesiotype from Well B, core 2916 ft. x55	18
6-9	*Globorotalia hirsuta* (d'Orbigny) 6, 7, spiral and umbilical views of plesiotype, x64. 8, 9, spiral and umbilical views of another plesiotype, x71. Both from Well A, core 3560 ft.	17
10-15	*Globorotalia menardii menardii* (d'Orbigny) 10, 11, spiral and umbilical views of plesiotype from Well A, core 3560 ft. x63. 12, 13, umbilical and spiral views of another plesiotype from Well A, core 3560 ft. x62. 14, 15 spiral and umbilical views of plesiotype from Well A, core 3574 ft. x58	18
16-18	*Globorotalia truncatulinoides* (d'Orbigny) Edge, spiral, and umbilical views of plesiotype from Well A, core 3104 ft. x54	20
22-25	*Globorotalia menardii multicamerata* Cushman and Jarvis 22, 23, spiral and umbilical views of plesiotype from Well B, core 2916 ft. x55. 24, 25, umbilical and spiral views of plesiotype from Well J, core 4062 ft. x36	19
26-28	*Globorotalia menardii tumida* (H. B. Brady) Umbilical, spiral, and edge views of plesiotype from Well A, core 2418 ft. 26, 28, x62. 27 x53	19

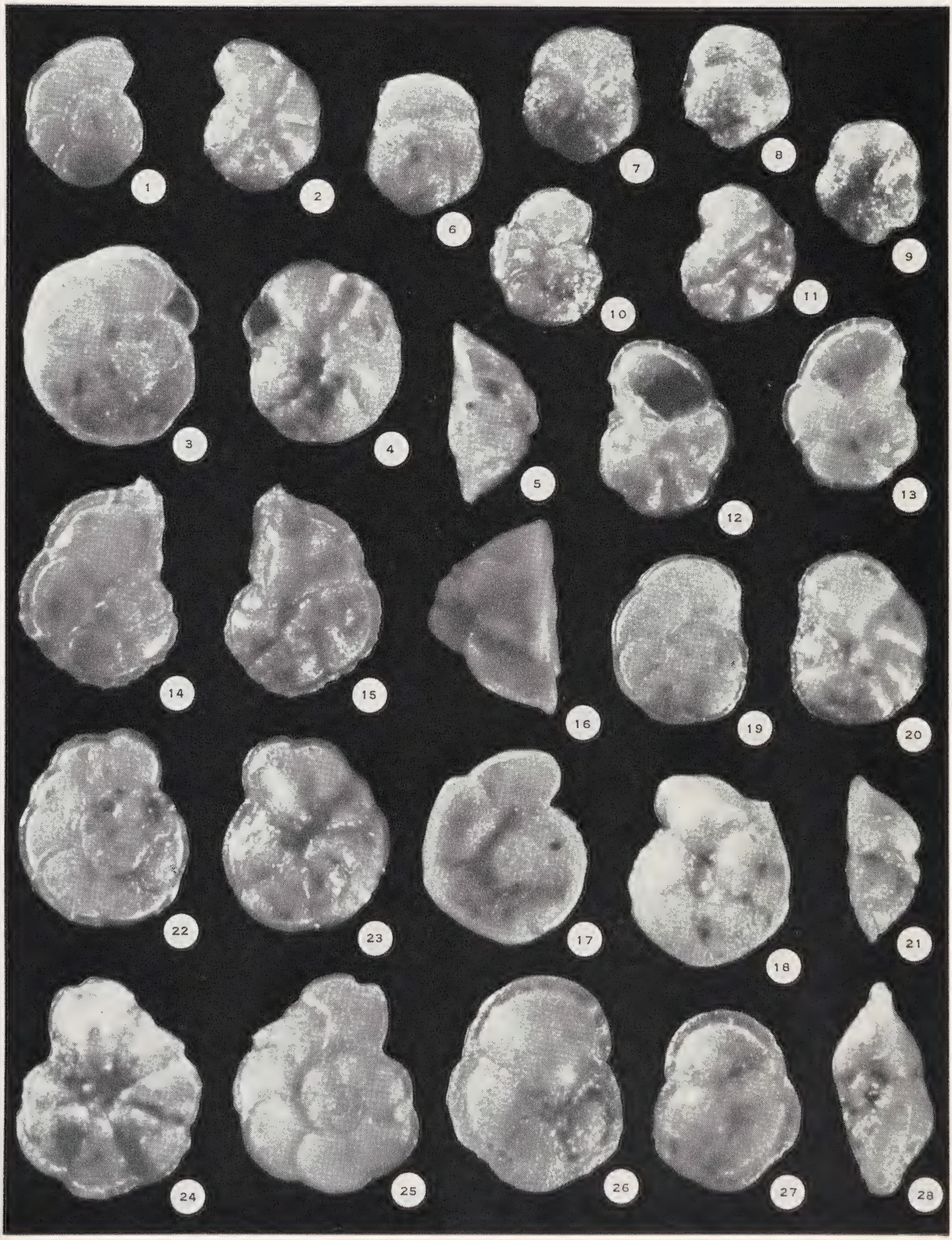

PLATE XIV

Plate XV

Figures		Page
1, 2	*Hanzawaia* cf. *H. concentrica* (Cushman) Opposite sides of specimen from Well A, core 2418 ft. x59	37
3, 4	*Hanzawaia concentrica* (Cushman) Opposite sides of plesiotype from Well A, core 578 ft. x38	37
5, 6	*Planulina exorna* Phleger and Parker Opposite sides of plesiotype from Well A, core 610 ft. x47	47
7, 8	*Cibicides umbonatus* Phleger and Parker Opposite sides of plesiotype from Well A, core 3258 ft. x57	31
9, 10	*Anomalinoides io* (Cushman) Opposite sides of plesiotype from Well A, core 578 ft. x56	22
11, 12	*Cibicides* aff. *C. protuberans* Parker Opposite sides of specimen from Well A, core 578 ft. x54	31
13, 14	*Hanzawaia strattoni* (Applin) Opposite sides of plesiotype from Well A, core 586 ft. x57	37
15	*Planorbulina mediterranensis* d'Orbigny Spiral side (drawing) of plesiotype from Well A, core 578 ft. x39	47
16, 17	*Cibicides wuellerstorfi* (Schwager) Opposite sides of plesiotype from Well A, core 3490 ft. x55	31
18	*Gypsina vesicularis* (Parker and Jones) Side view drawing of plesiotype from Well A, core 610 ft. x34	36
19, 20	*Planulina foveolata* (H. B. Brady) Opposite sides of plesiotype from Well C, core 1890 ft. x56	48
21-23	*Cibicides nucleatus* (Seguenza) Opposite sides and edge view of plesiotype from Well A, core 3560 ft. x40	30
24, 25	*Cibicides* aff. *C. robertsonianus* (H. B. Brady) Opposite sides (drawings) of specimen from Well A, core 578 ft. x152	31
26, 27	*Cibicides* aff. *C. floridanus* (Cushman) Opposite sides of specimen from Well A, core 3258 ft. x40	30

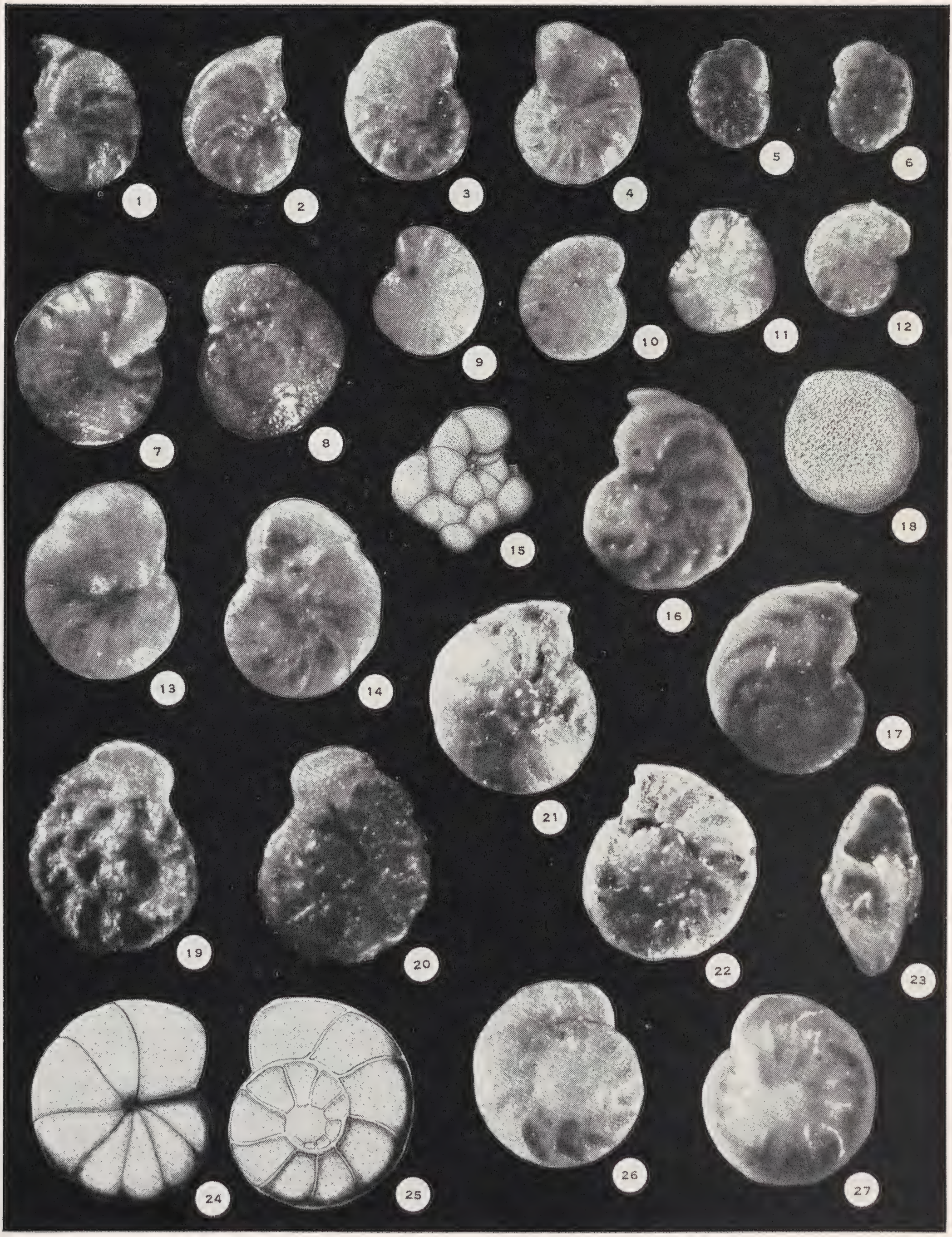

PLATE XV

ADDITIONS TO THE NEW WORLD TURBINELLAS

EMILY H. VOKES
TULANE UNIVERSITY

Inevitably, when one attempts a "complete" catalogue of any genus, there are almost certain to be omissions. Since the publication of *The Genus Turbinella in the New World* (Tulane Studies in Geology, vol. 2, no. 2, 1964), two species which were overlooked have come to the author's attention. In a desire to make the catalogue more nearly complete, they are here added.

TURBINELLA PERUVIANA COLOMBIANA (Clark)

Xancus peruvianus subsp. *columbianus* CLARK *in* CLARK and DURHAM, 1946, Geol. Soc. America, Mem. 16, p. 42, pl. 22, fig. 11.

Xancus peruvianus colombianus Clark. WOODRING, 1964, United States Geol. Surv., Prof. Paper 306-C, p. 286.

Diagnosis: "Shell heavy, spire less than height of body whorl (apical whorls and anterior end of the body whorl broken); sutures appressed; whorls with well-defined, upward-sloping shoulders, with narrow rather strongly appressed sutural collarlike area; shoulders ornamented by series of heavy rounded elongate nodes; there are 12 of these on anterior whorl of spire and about 15 on body whorl; surface also sculptured by series of faintly preserved spiral riblets; about 9 spirals on anterior whorl of spire; aperture elongate ovate; outer lip broken; inner lip covered by thin layer of callus; ridgelike callus growth in posterior angle of aperture; 3 heavy prominent plications on inner lip, the middle one of which is the longest and most prominent. Dimensions of holotype (the only specimen of the species found in the collections), U.C. Loc. S 60, spec. no. 35049: height of broken specimen about 86 mm, greatest width of body whorl 54.6 mm." (Clark and Durham, 1946)

Horizon: "Zone C", upper Eocene, Dist. of El Carmen, Bolivar, Colombia.

Discussion: This subspecies of *Turbinella peruviana* (Olsson) differs from the typical form in having a more inflated body whorl and a wider and more strongly sloping shoulder. The nodes on the shoulder are heavier and more pronounced. However, these distinctions are slight and it is possible that the two forms are synonymous, as they occur in beds which are considered by Clark and Durham to be equivalent in age.

TURBINELLA BUCCINA (Olsson and Richards)

Xancus buccina OLSSON and RICHARDS, 1961, Notulae Naturae, no 350, p. 9, pl. 2, fig. 1.

Diagnosis: "The shell is large or medium sized, solid, rather slender with a high spire of several whorls. The whorls have a low shoulder sloping upward and armed with a row of low spines or nodes and placed about one-third the whorl interval below the upper suture. There are about 14 nodes along the shoulder on the penultimate whorl and about 16 on the last whorl. The body whorl is large, produced forward into a straight, stout anterior canal, the end broken off in the type specimen. In the middle zone, the sides of the body whorl are fairly straight and wide and then slope rather sharply into the contour of the anterior canal. The columellar plaits, 3 or 4 in number, are narrow and sharp but are too deeply buried in matrix to show well." (Olsson and Richards, 1961)

Dimensions of holotype: height 105 mm, diameter 51 mm.

Holotype: ANSP 30813.

Horizon: Upper Oligocene. Borchina, Goajira [also spelled Guajira and Goagira] Peninsula, Colombia.

Discussion: The type and apparently only known specimen of this species is worn and imperfect, and its affiliations are therefore uncertain. In general it most closely resembles *Turbinella textilis* (Guppy) from the middle Miocene of Jamaica, being, however, considerably more slender in outline. Because of its poor preservation, and especially because of the lack of the nucleus, it seems

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best at this time not to attempt assignment to any particular lineage.

Almost simultaneously with the publication of *The Genus Turbinella in the New World,* the third part of Woodring's work on the paleontology of the Canal Zone appeared. In this paper he figures and discusses four species of *Turbinella* which occur in the Canal Zone. These are: *T.* cf. *peruviana* (Olsson) from the Gatuncillo Formation (middle Eocene); *T.* cf. *rex** (Pilsbry and Johnson) from the Culebra Formation (lower Miocene); *T. valida** G. B. Sowerby from the Gatun Formation (middle Miocene); and *T. falconensis* (H. K. Hodson) also from the Gatun Formation. This latter smooth species Woodring makes a subspecies of the strongly knobbed *T. valida* stating, "These two forms have the same pattern of weak, widely spaced spiral cords on the main part of the body whorl and the same pattern of somewhat exaggerated growth lines between the suture and the shoulder." (1964, p. 287). As these traits are found to a greater or less degree throughout the genus such an alliance does not seem justified.

---

* For a discussion of the identity of these two species the reader is referred to p. 47-48 of the author's previous *Turbinella* paper.

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ASSISTANT PROFESSOR OF GEOLOGY
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REVISION OF THE FORAMINIFERAL FAMILY PSEUDOPARRELLIDAE VOLOSHINOVA
JERE H. LIPPS
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CONTENTS

Page

I. ABSTRACT 97
II. INTRODUCTION 98
III. STRATIGRAPHY 100
IV. STRUCTURE 103
V. OCCURRENCE OF PRODUCTIVE SANDS 108
VI. STRUCTURAL GROWTH AND GEOLOGIC HISTORY 110
VII. SUMMARY AND CONCLUSIONS 112
VIII. LITERATURE CITED 114
TABLE I: Total accumulated production figures 100

ILLUSTRATIONS

PLATE I: Type logs 102
PLATE II: Fault-data map 105
PLATE III: Structure map—3,200-foot Pliocene sand 107
PLATE IV: Structure map—6,200-foot Miocene sand 109
PLATE V: Structure map—*Planulina* Zone 111
PLATE VI: Isopachous map—3,200-foot Pliocene to 6,200-foot Miocene Interval 113
PLATE VII: Isopachous map—6,200-foot Miocene to top of *Planulina* Interval 115
PLATE VIII: Cross section A-A′ ..... opposite page 102

I. ABSTRACT

The Abbeville-Perry-South Perry structure is located in the Miocene oil- and gas-producing trends of Vermilion Parish, Louisiana. The strata encountered by drilling are primarily Pliocene, Miocene, and Oligocene in age. Wells drilled to sufficient depth encounter three distinct facies: first, a shallow-water massive Pliocene and Miocene near-shore to continental sand facies; then, an intermediate facies of alternating sands and shales from the Miocene continental-shelf environment; and, finally, the thick deep-water shale facies of the early Miocene and late Oligocene.

Structurally, the Abbeville-Perry-South Perry feature is a faulted, elongate anticline that trends north-northwest. It is oriented normal to the regional strike of the beds. All faults are normal and include both down-to-

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the-basin and up-to-the-basin faults. The former are generally regional in extent; the up-to-the-basin faults are smaller compensating faults confined to the Abbeville-Perry-South Perry structure. The fault throw generally increases gradually with depth. Faults decreasing with depth appear to "die-out" in the bathyal shales.

Individual beds thicken onto the downthrown sides of the faults and thin toward the crest of the structure. The amounts of thickening or thinning generally increase gradually with depth. Thus, fault movement and anticlinal folding were contemporaneous with sedimentation more-or-less continuously from Oligocene to Pliocene time. These tectonic movements were greatest during Oligocene and Lower Miocene time.

The Abbeville-Perry-South Perry structure probably originated from anticlinal folding and faulting in the region of the continental slope during early Miocene and Oligocene time. As the hinge line (or shelf edge) migrated seaward across the area, the structure became positioned closer to the shoreline until in Pliocene time it was near the shoreline. Anticlinal growth and fault movement were greatest at the time when the structure was located in the environment of the continental slope and outer continental shelf. The structural activity steadily decreased after Lower Miocene time as the hinge line with its unstable environment continued to migrate farther basinward.

II. Introduction

Abbeville field is located two to three miles west-northwest of the city of Abbeville in Township 12 South, Range 3 East, Vermilion Parish, Louisiana. The Perry and South Perry fields are located in Vermilion Parish, Louisiana, two to four miles south of the Abbeville field (see figure 1).

Abbeville was known to be a prospect as early as 1929, when reflection seismic surveys conducted by the Humble Oil and Refining Company and the Atlantic Oil Producing Company showed evidence of a structure in the area. The Stanolind Oil and Gas Company also surveyed the Abbeville area with the reflection seismograph in 1935. Both subsurface geology and geophysical exploration techniques were used in locating the Perry and South Perry fields. The discovery well for Abbeville field was the Continental No. 1 Hebert (sec. 20, T12S, R3E). In March, 1937, the well flowed 52 barrels of 41° API gravity oil and approximately 3 million cubic feet of gas per day through perforations at 7,666 feet to 7,682 feet. The confirmation well, the Continental No. 1 Brookshire (sec. 66, T12S, R3E) was completed in November, 1937. The initial production through perforations 7,884 feet to 7,890 feet was 514 barrels of 43.1° API gravity oil and 1,140,000 cubic feet of gas through a 3/16-inch choke with a tubing pressure of 2,150 pounds. In December, 1937, the discovery well was recompleted through perforations 7,886 feet to 7,892 feet. The well flowed 203 barrels of 41° API gravity oil and 243,000 cubic feet of gas. The total production for Abbeville field in 1937 was 17,185 barrels of oil and 157,305,000 cubic feet of gas. This production came entirely from the Hebert No. 1 and Brookshire No. 1 wells.

One hundred and thirty-four tests have been drilled in Abbeville field since 1937. Sixty-seven of these are presently producing wells; sixty-seven were dry holes. The records of the Louisiana Geological Survey (at the end of 1963) list 44 oil wells and 23 gas wells for Abbeville field. It has been calculated that the producing wells were completed in 240 feet of net oil sand and 150 feet of net gas sand.

The discovery well for Perry field, the Texas Gas Exploration No. 1 Noel (sec. 5, T13S, R3E), was completed in 1957 as a gas well in 50 net feet of gas sand from 10,894 feet to 10,944 feet. The initial production through perforations 10,935 feet to 10,940 feet was 19 barrels of 49.9° API gravity oil per day, plus 2.6 million cubic feet of gas, on a 12/64-inch choke with a tubing pressure of 3985 pounds and a gas-oil ratio of 143,586:1. The Texas Gas Exploration No. 2 Noel (sec. 5, T13S, R3E), drilled as an eastern offset to the discovery well, was an attempt to confirm the Perry field. The test was dry and abandoned in December, 1957, with a total depth of 11,614 feet. The next well drilled was the Texas Gas Exploration No. 1 De Marcy (sec. 6, T13S, R3E). The test, located about ½ mile west of the discovery well, confirmed the Perry field with a completion in the same 50-foot gas sand encountered in the Noel No. 1. The top of this sand was encountered in the De Marcy well at 10,844 feet, 50 feet higher

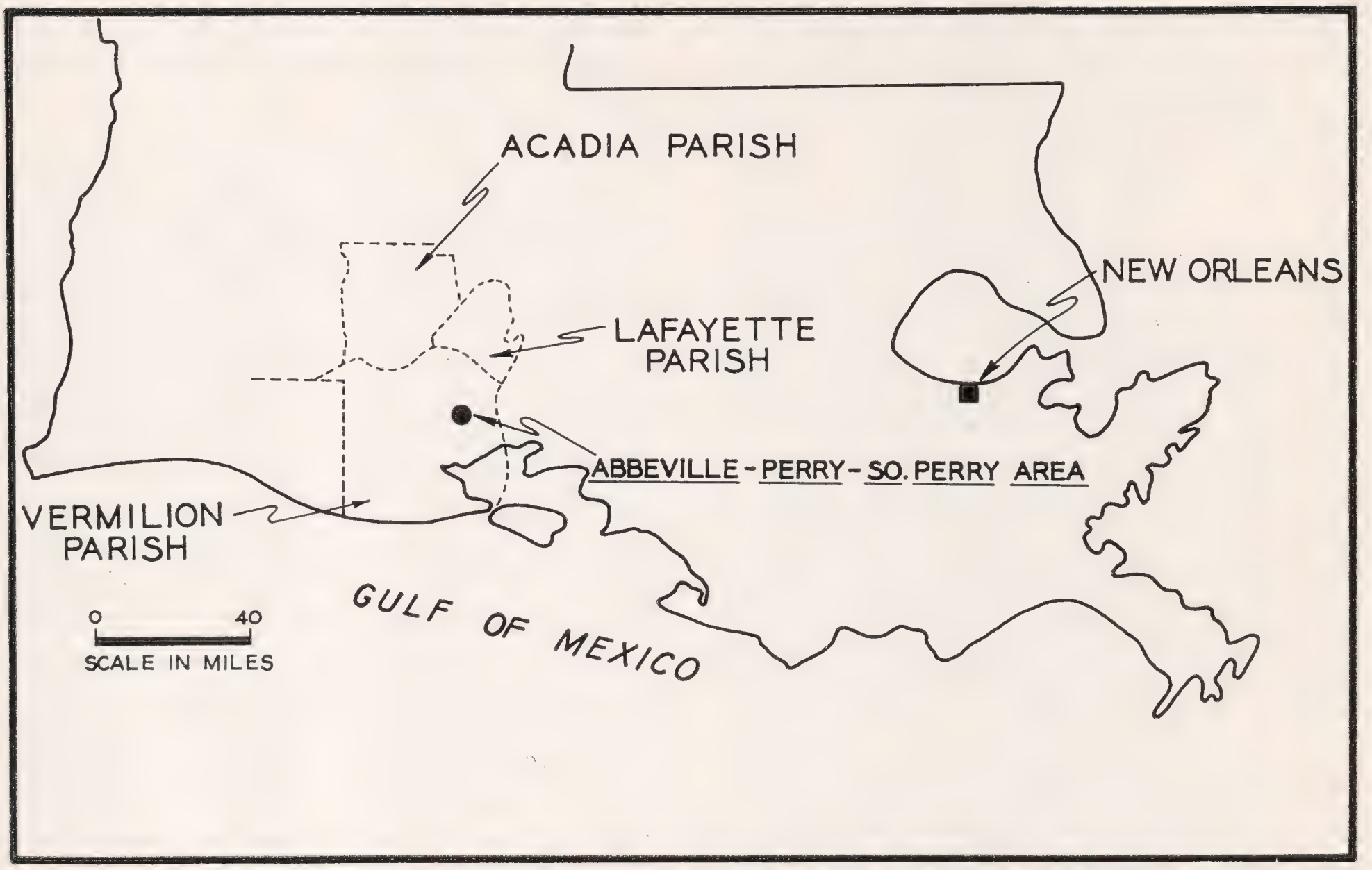

Figure 1. Map of South Louisiana showing the location of the Abbeville-Perry-South Perry structure.

than in the discovery well. The De Marcy No. 1 completion was followed by the drilling of three dry holes, two in 1958 and one in the early part of 1959. The total depths of these three dry holes were near 11,000 feet. Two other tests, the No.1 LeBouef (sec. 10, T13S, R3E), and No. 1 Champagne (sec. 3, T13S, R3E), drilled by the Hope National Gas Company, were drilled recently in Perry field. Both wells were completed in a 20-foot gas sand below 11,000 feet. By the end of 1963, eight tests had been drilled at Perry. Four of these are producing gas wells; the other four are dry holes. The producing wells were completed in approximately 70 feet of gas sand.

The discovery well for South Perry field was the Tennessee Gas No. 1 Detraz (sec. 17, T13S, R3E). The well was completed in 1960 as a gas-distillate discovery in 36 net feet of sand from 14,713 feet to 14,798 feet. The well flowed initially (through perforations at 14,717 feet to 14,732 feet) 185 barrels of 46.8° API gravity oil and 4,775,000 cubic feet of gas through a 12/64-inch choke with a tubing pressure of 6100 pounds, and a gas-oil ratio of 25,810:1. The well also yielded 0.1 per cent basic sediment and water.

Six wells have been drilled at South Perry. All of these tests, except the Detraz No. 1, were found dry and abandoned. Two of the dry holes, the Phillips No. 1 Noel (sec. 9, T13S, R3S) and the Feazel No. 1 Mouton (sec. 15, T13S, R3E), were drilled several years prior to the completion of the Detraz No. 1. The discovery well is located ½ mile west of the Mouton test and ¾ mile southwest of the Noel No. 1. The Mouton No. 1 was drilled to a total depth of 11,520 feet; the Noel No. 1 to a total depth of 13,502 feet. The other dry holes in the South Perry area were drilled subsequent to the discovery well. The Sinclair No. 1 Mestepey (sec. 15, T13S, R3E), located ½ mile south of the Detraz No. 1, was found dry and abandoned in 1961 at a total depth of 15,455 feet. Another test, the Plymouth No. 1 Duhon (sec. 7, T13S, R3E), drilled to a total depth of 12,700 feet, was also found dry and abandoned in 1961. The most recently drilled test in the area, the Vaughn No. 1 Dumond Heirs (sec. 8, T13S, R3E), was found dry and abandoned in 1962 at a total depth of 12,613 feet. The Duhon No. 1 and the Dumond Heirs No. 1 are to the northwest of the discovery well.

Total accumulated production figures to-

date (from the Louisiana Department of Conservation Annual Oil and Gas Report for 1962) for the Abbeville, Perry, and South Perry fields are given in table 1.

Acknowledgments

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III. Stratigraphy

The stratigraphic section in the Abbeville-Perry-South Perry fields consists mainly of strata of Pliocene, Miocene, and Oligocene age. The general nature of the deposits can be seen on the two type logs (plate I) and on the cross section A-A′ (plate VIII). The electrical log of the Richardson and Bass-Amerada No. 1 Brookshire (sec. 5, T12S, R3E) was chosen as the type log for Miocene and Oligocene strata in the northern portion of Abbeville field. The electrical log of the Tennessee Gas No. 1 Detraz (sec. 17, T13S, R3E) was used as a type log for Lower Miocene and Oligo-Miocene strata in the South Perry and Perry areas and in the southern portion of Abbeville field. The Brookshire No. 1 (total depth, 16,020 feet) is one of the deepest tests in Abbeville field. The Detraz No. 1 (total depth, 15,856 feet) is the deepest well in the Perry-South Perry area. The missing section due to faulting in both wells has been restored in the type logs. Important diagnostic faunal markers have been placed on the type logs and on cross section A-A′.

Wells drilled to sufficient depth in the Abbeville-Perry-South Perry area encounter three distinct facies: first, a shallow-water massive Pliocene and Miocene near-shore to continental sand facies; then, an intermediate facies of alternating sands and shales from the Miocene continental shelf; and finally, the thick deep-water shale facies of the early Miocene and late Oligocene continental slope. The interpreted environments of deposition for these facies are based on the lithologic nature of the strata and the paleoecological interpretation of the associated faunas.

Sediments presently being deposited along the Louisiana Gulf Coast consist of sands, near shore; sands and muds farther out on

Table 1

Total Accumulated Production Figures for the Abbeville, Perry, and South Perry Fields

Fields	Oil, barrels	Condensate, barrels	Gas, MCF
Abbeville	3,063,218	1,298,248	67,451,671
Perry	None	38,577	6,381,606
South Perry	None	10,694	301,372

the continental shelf; and muds on the continental slope (Lowman, 1949; and Lynch, 1954, p. 79). The change from shelf sands and muds to the muds of the continental slope is abrupt and occurs at the shelf edge (Weaver, 1955). A marked basinward increase in slope and dip of the beds also takes place at the shelf edge. A similar change in facies and dip of strata occurs in Tertiary formations (Lowman, 1949; Limes and Stipe, 1959; and Thorsen, 1964). Thus, lithologies of Tertiary strata can be used to interpret environments of deposition. The abrupt changes from sands and shales to thick shale sections accompanied by steepened dips especially can be used to locate former shelf edges in the Tertiary.

Paleoecological interpretations made in this investigation are based primarily upon the work of Lowman (1949), Crouch (1956a and b), and Skinner (1964, personal communications). Lowman and Crouch list environments of deposition for stratigraphic units containing certain diagnostic Foraminiferida of the Tertiary along the Gulf Coast. Skinner's more recent work was used to verify and supplement the older work of Lowman and Crouch. Paleoecological zones, as defined by Lowman, Crouch, and Skinner, are based primarily upon the ecological study of species that have Recent counterparts. For those species that do not have Recent counterparts, the paleoecological character of the assemblages is inferred by other associated species that do have Recent counterparts.

The oldest strata encountered in the Abbeville-Perry-South Perry area south of fault C belong to the Abbeville Zone which is Oligo-Miocene in age.* The Abbeville is composed almost entirely of shale. A few thin, erratic, shaly-sand bodies are present. The zone represents a deep-water facies deposited on the continental slope. The top of the Abbeville Zone is encountered along the crest of the Abbeville structure at approximately 12,700 feet and in South Perry field at 14,250 feet. Over 1,200 feet of Abbeville strata were drilled in the Brown No. 1 LeBouef (sec. 38, T12S, R3E). This well was still in the Abbeville Zone at the total depth of 14,515 feet.

The oldest beds encountered north of fault C belong to the Anahuac Formation. The Anahuac is Late Oligocene in age and is divisible into three biostratigraphic zones, from youngest to oldest: the *Discorbis, Heterostegina,* and *Marginulina.* The *Marginulina* Zone is a deep-water shale facies deposited in the environment of the continental slope. The only notable sand development in the *Marginulina* Zone is a 80-foot sand body found in the Richardson and Bass-Amerada No. 1 Brookshire at a depth of 15,039 feet. Over 3,500 feet of *Marginulina* strata were encountered in the Union Texas Natural Gas Company No. 1 Hebert (sec. 20, T12S, R3E) at a depth of 15,080 feet. *Marginulina* strata are overlain by 800 to 1,200 feet of *Heterostegina* shales. A few, thin, limy-shale streaks are present. The zone is encountered at depths ranging from 10,800 feet just north of fault C to 12,307 feet on the north flank of Abbeville field. *Heterostegina* strata were deposited in the neritic environment of the continental shelf. The *Heterostegina* Zone is overlain by continental-shelf shales of the *Discorbis* Zone. *Discorbis* strata consist almost entirely of shale, vary from 500 to 700 feet in thickness, and are confined to the northern portion of Abbeville field.

The deepest test in the area, the Sun Oil Company No. 1 Mailbes (sec. 44, T12S, R3E), located on the east flank of the Abbeville structure, penetrated a thick sequence of Anahuac beds. After crossing a fault with a throw of 1,100 feet (fault C) at 11,500 feet, the Mailbes No. 1 drilled through more than 5,000 feet of Anahuac strata between 11,900 feet and the total depth of 17,201 feet.

The Abbeville and Anahuac are overlain by the early Miocene strata of the *Planulina* Zone. North of fault C this zone occurs at depths of about 10,600 feet and varies in thickness from 300 to 700 feet. South of fault C the *Planulina* Zone varies in thickness from 1,100 feet at the crest of the Abbeville structure to nearly 1,300 feet in South Perry field. This zone is encountered south of fault C at depths ranging from

* The age of the Abbeville Zone is controversial. Some workers believe the Abbeville to be (1) post-Anahuac (early Miocene in age), or (2) equivalent to the Anahuac Formation (Oligocene in age). Others, such as Tipsword, (1962, p. 39), consider the Abbeville to be time transgressive and thus Oligo-Miocene in age. In this report the writer follows the suggestion of Tipsword that the Abbeville Zone is Oligo-Miocene in age.

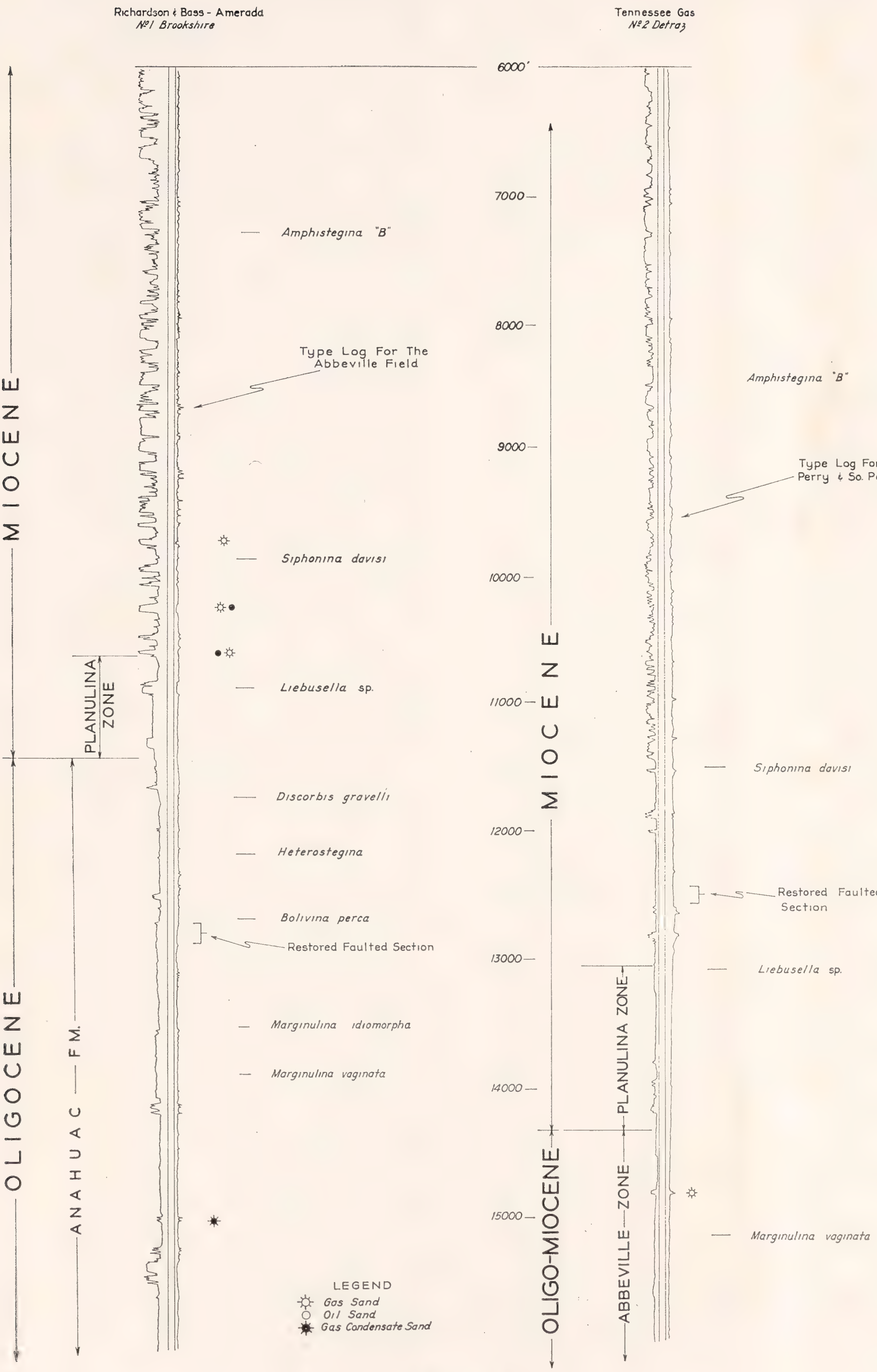


Plate I

Type logs for the Abbeville, Perry and South Perry fields

SOUTH PERRY FIELD

TENN. GAS
№ 1 Detra:3

6000

7000

8000

9000

10000

11000

— 11510 *Siphonina davisi*

12000

13000

— 12980 *Liebusella* Sp.

FAULT "K"

14000

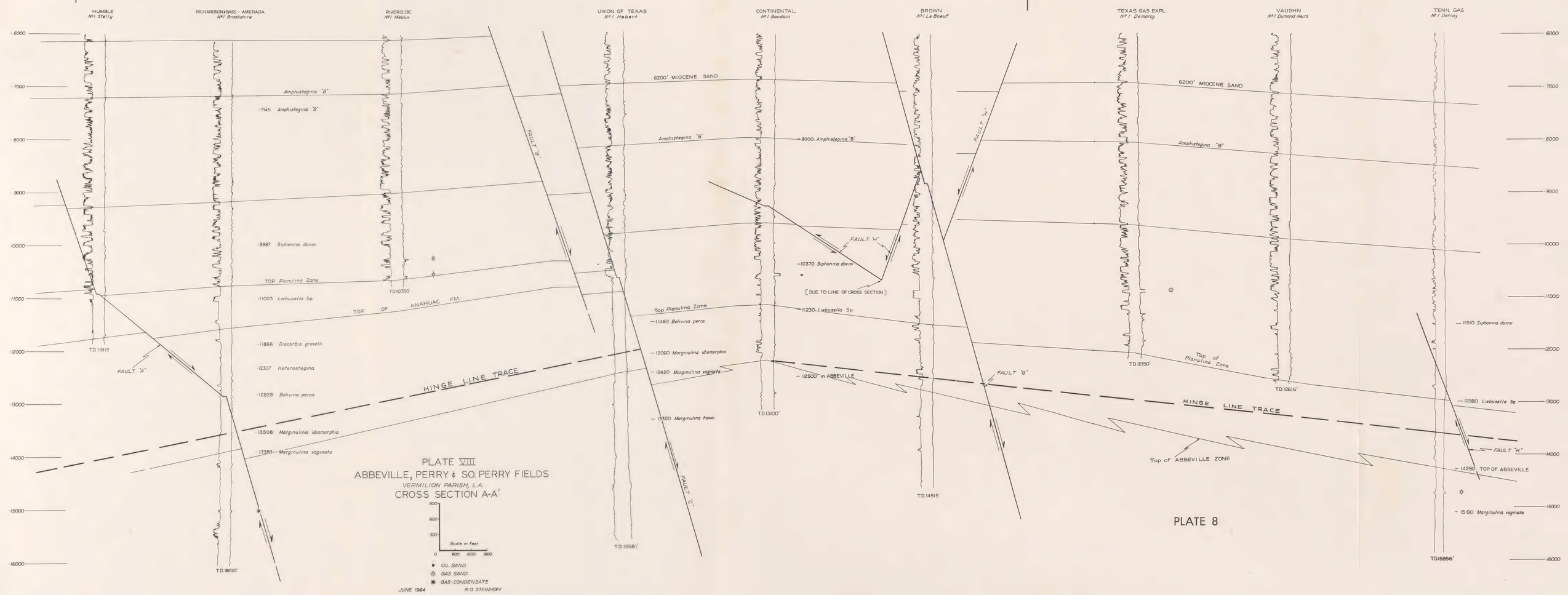
— 14250 TOP OF ABBEVILLE

15000

— 15190 *Marginulina vaginata*

TD 15856'

16000


ABBEVILLE FIELD
PERRY FIELD
SOUTH PERRY FIELD
HUMBLE
N°1 Stelly
RICHARDSON & BASS - AMERADA
N°1 Brookshire
RIVERSIDE
N°1 Meaux
UNION OF TEXAS
N°1 Hebert
CONTINENTAL
N°1 Boudoin
BROWN
N°1 Le Boeuf
TEXAS GAS EXPL.
N°1 Demarcy
VAUGHN
N°1 Dumond Heirs
TENN. GAS
N°1 Dietrag
6000
7000
8000
9000
10000
11000
12000
13000
14000
15000
16000
Amphistegina "B"
-7145 Amphistegina "B"
-9987 Siphonina davisi
TOP Planulina Zone
-11003 Liebusella Sp.
TOP OF ANAHUAC F.M.
-11866 Discorbis gravelli
-12307 Heterostegina
-12828 Bolivina perca
-13508 Marginulina idiomorphia
-13383 Marginulina vaginata
TD 11812
TD 10750'
TD 16010'
FAULT "A"
FAULT "B"
FAULT "C"
HINGE LINE TRACE
6200' MIOCENE SAND
Amphistegina "B"
Top Planulina Zone
-11460 Bolivina perca
-12060 Marginulina idiomorphia
-12420 Marginulina vaginata
-13320 Marginulina howei
TD 15581'
-8000 Amphistegina "B"
FAULT "H"
-10370 Siphonina davisi
[DUE TO LINE OF CROSS SECTION]
-11230 Liebusella Sp.
-12500 in ABBEVILLE
TD 13100'
FAULT "G"
FAULT "H"
TD 14515'
6200' MIOCENE SAND
Amphistegina "B"
TD 12150'
Top of Planulina Zone
TD 12615'
Top of ABBEVILLE ZONE
-11510 Siphonina davisi
-12980 Liebusella Sp.
FAULT "K"
-14250 TOP OF ABBEVILLE
-15190 Marginulina vaginata
TD 15856'
PLATE VIII
ABBEVILLE, PERRY & SO. PERRY FIELDS
VERMILION PARISH, LA.
CROSS SECTION A-A'
900'
600'
300'
Scale in Feet
0
600
1200
1800
OIL SAND
GAS SAND
GAS-CONDENSATE
JUNE 1964
R.O. STEINHOFF
PLATE 8

11,130 feet near this fault to 12,980 feet in South Perry field. Although several persistent sand bodies are present, the zone is predominantly shale. In the Richardson and Bass-Amerada No. 1 Brookshire north of fault C the *Planulina* Zone consists of two 70- to 90-foot sand bodies separated by nearly 300 feet of shale. In South Perry field the zone consists of nearly 1,000 feet of shale and two 50-foot sand bodies at depths of approximately 14,000 feet. The strata of the *Planulina* Zone in the Abbeville-Perry-South Perry area were deposited in the continental-shelf environment.

The *Planulina* Zone is overlain by the Lower Miocene sediments of the *Siphonina davisi* Zone. Approximate thicknesses of this zone are 700 feet at the crest of the Abbeville structure, 800 to 900 feet on the north flank of Abbeville field, and 1,400 feet in the Perry area. The zone is encountered at depths ranging from 9,900 feet to 11,500 feet. The alternating sands and shales of the *Siphonina davisi* Zone are from the continental shelf. Overlying the *Siphonina davisi* Zone are nearly 2,300 feet of Lower Miocene and lower Middle Miocene (*Amphistegina* "B" Zone) massive sands, and alternating sands and shale bodies. These sediments also were deposited on the continental shelf. The *Amphistegina* "B" Zone is overlain by nearly 3,000 feet of massive Miocene sands.

The first occurrence of *Bigenerina floridana* is interpreted as the boundary between the Miocene and the overlying Pliocene. *Bigenerina floridana* occurs at a depth of about 5,000 feet in the Abbeville-Perry-South Perry area. The Pliocene consists of a great thickness of massive sands.

IV. Structure

The Abbeville-Perry-South Perry structure is a faulted, elongate north-northwest trending anticline which extends for nearly nine miles normal to the regional strike of the beds. The average width is between three and four miles. The anticline is cut by numerous normal faults (see plates III to V). The two regional faults shown on the fault map prepared by Wallace (1963) are faults A and C of this report. Both faults are down-to-the-basin and trend east-northeast. All other faults strike either north-northwest (faults, E, G, H, and M) or northeast (faults B and N). The fault-plane dips calculated for the area are: fault A, 63 degrees; fault B, 69 degrees; and faults G and H, 56 degrees. Data related to faults encountered in the Abbeville-Perry-South Perry area have been placed alongside the appropriate well on a composite fault-data map (plate II).

Structural contour maps were prepared on horizons within the Pliocene (plate III) and Miocene (plate IV) and on top of the *Planulina* Zone (plate V). Isopachous maps (plates VI and VII) were constructed for the intervals between the horizons contoured on the structural maps. Cross section A-A′ (plate VIII) is taken along the axis of the Abbeville-Perry-South Perry structure.

The structure map contoured on the 3,200-foot Pliocene sand (plate III) shows a faulted, elongate anticline. Six faults (faults B, C, E, F, G, and H) were mapped on this horizon. The throw of the faults varies from 50 feet to as much as 350 feet. The largest faults (faults B and C) are downthrown to the south or southeast. Areas of closure are mapped on the downthrown side of fault C, the upthrown side of fault H, and along fault B. The amount of closure associated with these structural highs varies from less than 100 feet just southeast of fault B to over 250 feet south of fault C. Other noteworthy features shown on plate III include the graben formed by faults F, G, and H; the strong southward "nosing" of the contours between faults G and H; and the 100 to 150 feet of north dip into fault C.

Plate IV, the structure contour map on the 6,200-foot Miocene sand, also shows the faulted, elongate, anticlinal structure. All the faults mapped at the Pliocene horizon are present also on the map of the Miocene horizon. The faults have increased fault throw at the Miocene horizon in amounts ranging from 50 to 150 feet. For example, the largest faults (faults B and C) have displacements at the Miocene horizon of 450 feet and 500 feet, respectively. Several additional faults (faults A, F, I, and J) were mapped on plate IV. All of these have 60 feet of throw or less. Faults A and F are down-to-the-basin; faults I and J are up-to-the-basin.

Plate IV also illustrates "fault migration" with depth. The largest fault (fault C) is 1,000 to 2,000 feet south of its position at the Pliocene datum. Other faults have shifted approximately 1,800 feet. The crest of the structural high on the downthrown side of fault C also has shifted southward with faults

C and F. The apices of other structural highs (such as the one on the downthrown side of fault B) have remained essentially stationary despite the migration of nearby faults. The southward shift of the apex of the closure on the upthrown side of fault B apparently is not related to the southeastward migration of fault B.

The dip of the beds at the 6,200-foot Miocene horizon is approximately 150 to 200 feet per mile. This represents a 50- to 100-foot per mile increase over the rates of dip observed on the map of the 3,200-foot Pliocene horizon. On plate IV there is shown approximately 100 feet of north dip into fault C and the graben area between faults F, G, and H. The northward dip into fault C is about the same as that in the Pliocene. The graben is narrower (on plate IV) due to the shift of position of faults F, G, and H. On the Miocene horizon the contours "nose" southward in South Perry field and southeastward near the Hunter No. 1 Boudreaux, a wildcat well (sec. 37, T13S, R3E).

Plate V, the structure map contoured on the *Planulina* Zone, shows a narrow, elongate anticline cut by numerous faults. The dip of the beds range from 400 feet per mile to 500 feet per mile which is considerably greater than on the previous map. Most of the faults mapped at the 6,200-foot Miocene horizon also are present in the *Planulina* Zone. The faults increase in throw in amounts ranging from 90 feet to over 500 feet. Most have a throw of about 200 feet. The greatest increase occurs along fault C. It increased from 500 feet at the Miocene horizon to 1,000 feet (on plate V). Faults D, F, J, M, and portions of faults H and G, mapped on the 6,200-foot Miocene horizon are not present in the *Planulina* Zone. Additional faults K, M, and N are mapped on plate V. The displacements on these faults range from 80 to 200 feet. Faults M and N are at Abbeville field, and fault K is present at South Perry field.

Each fault mapped at the 6,200-foot Miocene horizon that extends downward into the *Planulina* Zone has shifted with depth approximately 2,000 feet. The apex of the structural high on the downthrown side of fault C has shifted slightly southward with the southward movement of fault C. Apices of the other structural highs have remained essentially stationary.

Two of the major faults (faults G and H) forming the graben south of fault C extend downward into the *Planulina* Zone. However, fault G, south of fault N, ends abruptly against fault H; and, north of fault N, fault H terminates abruptly against fault G. These abrupt terminations take place in the Lower Miocene section well above the top of the *Planulina* Zone. Thus, the graben as mapped in the Pliocene and Miocene does not occur in the *Planulina* Zone.

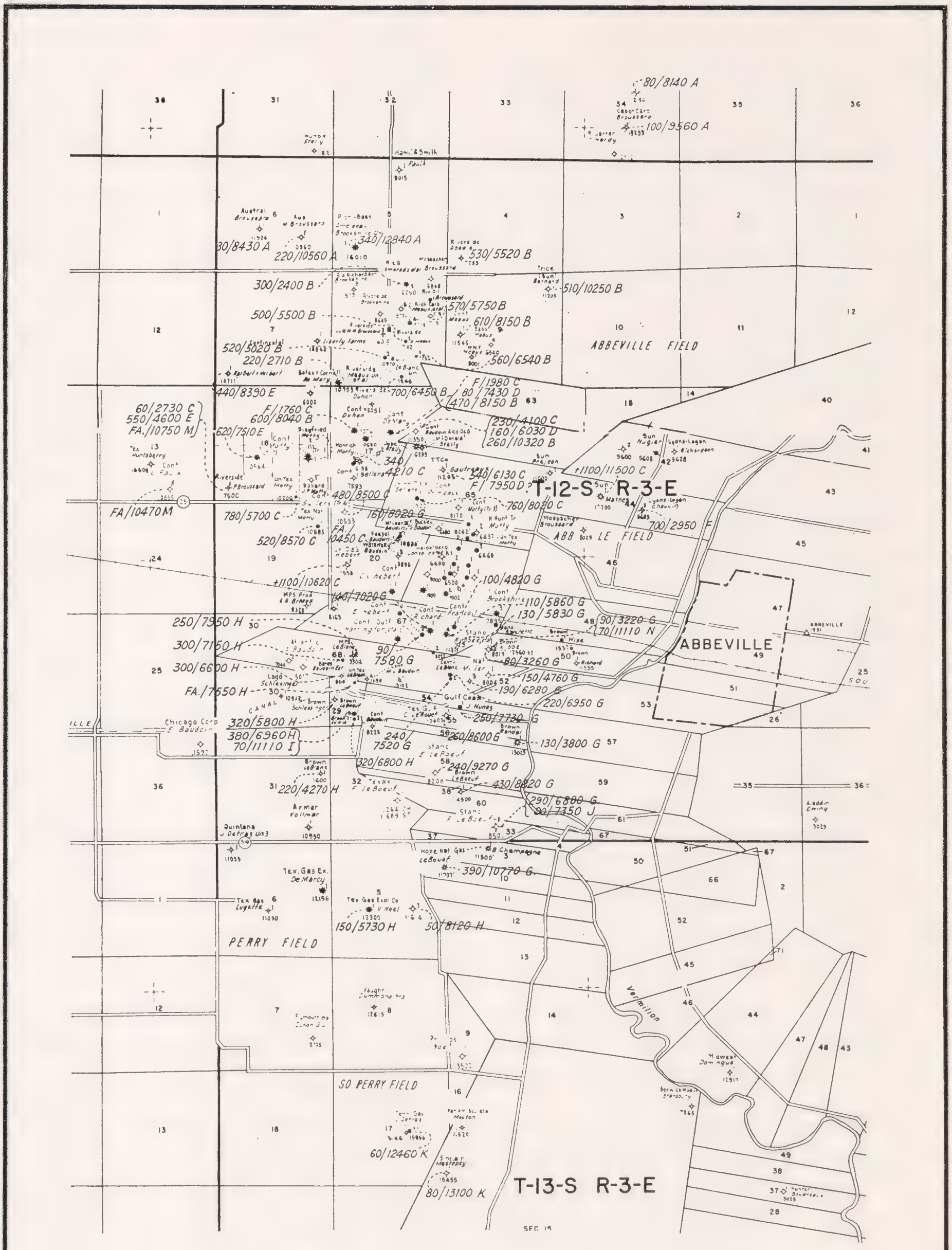
There is a strong southwestward "nosing" of contours in the vicinity of the Hunter No. 1 Boudreaux, a continuation of that noted on the Miocene map. This structural configuration extends toward the Bancker field, located approximately one to two miles south of the Hunter No. 1 Boudreaux. In South Perry field, the slight southward "nosing" of contours is a continuation of that mapped at the Miocene horizon.

Plate VI is an isopachous map of the interval between the 3,200-foot Pliocene and 6,200-foot Miocene mapping horizons. It shows thinning of the beds toward the crest of the Abbeville-Perry-South Perry anticline. Areas of greatest thinning correspond closely to the structurally highest portions of the anticline. An exception occurs on the downthrown side of fault C where the closed area of greatest thinning lies about one mile south-southwest of the apex of the structural high mapped on the Pliocene horizon.

The strata thicken across faults A and C to the south. Average thicknesses are: north of fault A, 2,974 feet; between faults A and C, 3,031 feet; and south of fault C, 3,296 feet. In the fault blocks between faults A and C, and south of fault C the beds are generally thicker on the downthrown sides of the faults. Examples include the 100 feet or more of thickening present on the downthrown side of fault B and in the graben area between faults G and H.

The amount of flank-to-crest thinning between faults A and C is about 140 feet and is generally greater south of fault C. Over 400 feet of thinning is associated with the structural high located between faults F and G. Approximately 170 feet of thinning takes place between faults G and H, and over 200 feet to the west of fault H.

As shown on plate VI, the strata thicken into the downthrown sides of the faults, especially along faults A, B, C, and G. The



ABBEVILLE-PERRY-SOUTH PERRY AREAS

VERMILION PARISH, LA.

FAULT DATA MAP

June 1964 R. O. Steinhoff

PLATE II

amount of thickening associated with each of these faults is less than 100 feet.

There is a large amount of flank-to-crest thinning shown on the isopachous map of the interval between the 6,200-foot Miocene horizon and the top of the *Planulina* Zone (plate VII). Approximately 360 feet of thinning is measured in the area bounded by faults A, B, and F, and over 1,000 feet in the area south of fault C. Both amounts represent a tremendous increase compared with the younger interval.

The interval between the 6,200-foot Miocene horizon and the top of the *Planulina* Zone thickens downdip across faults A and C (plate VII). The average thicknesses are 4,452 feet in the fault block between faults A and C, and 5,076 feet south of fault C. These changes are considerably greater than those observed across fault C on the previous isopachous map. Considerable thickening also occurs across fault N. The beds on the downthrown side of fault N are nearly 200 feet thicker than to the north. Little or no thickening of beds is noted across the other faults. Also, abnormal thickening on the downthrown blocks northward toward faults A and C is present (plate VII) in amounts of over 300 feet along fault A and approximately 200 feet along fault C.

Cross section A-A′ (plate VIII) extends along or very close to the crest of the Abbeville-Perry-South Perry anticline (the line of section is shown on plate III). Cross section A-A′ especially shows:

1) An anticlinal structure cut by normal faults.

2) Correlation lines drawn on the top of the 6,200-foot Miocene sand body and through several of the main faunal markers in the area.

3) A dashed line that represents the seaward migration of the shelf edge with time. The shelf edge is termed a "hinge line" by many Gulf Coast geologists including Weaver (1955), Hardin and Hardin (1961, p. 244), Skinner (1963, personal communication), and Steinhoff (1964). Steinhoff (1964, p. 164) states:

> "A hinge line in Gulf Coast terminology is a tectonic zone of weakness downdip from which the sedimentary beds thicken abnormally basinward. The thickening is accompanied by a sharp increase in the rate of southward dip. Updip from the zone are shelf sediments which thicken and dip gently seaward. The hinge line marks the place where the beds first begin to show an increase in the rate of thickening and dip. It is the boundary between bathyal-type shales of the continental slope and neritic sediments of the continental shelf."

In the Abbeville-Perry-South Perry area the boundary is underlain by the deep-water shales of the Abbeville Zone and Anahuac Formation and overlain by the neritic beds of the Miocene. Most of the tectonic activity in the area took place on the continental slope in front of the migrating edge of the continental shelf. As the hinge line with its unstable environment passed southward, structural development continued upward into the neritic zone but at a reduced rate. The trace of the hinge line or "hinge line surface" is now arched and faulted. This is due to structural movement that took place in the area after the transition of the hinge line.

4) The stratigraphic nature of the sediments from the Anahuac Formation and Abbeville Zone into the Middle Miocene. Most of the sand and shale bodies above the hinge line surface are persistent throughout the area. Correlation difficulties encountered above the hinge line surface are mostly within the massive sand section of the Miocene and Pliocene. Correlation is also difficult in the bathyal section below the hinge line. Sands deposited in the bathyal zone are erratic and seldom can be traced over large areas.

5) Down-to-the-basin faults (faults A and C) increasing in throw with depth down to the hinge line. Below the hinge line both faults show a decrease in throw. Fault B decreases in throw with depth and dies-out before reaching the hinge line. In South Perry field the Tennessee Gas No. 1 Detraz is cut by a small down-to-the-southwest fault that terminates in the Miocene strata. Faults C and H form a graben in the vicinity of the Brown No. 1 LeBoeuf. The peculiar configuration of fault H on cross section A-A′ is due to the direction of the line of section. Fault G is actually down-to-the-west but it has the appearance on plate VIII of being down-to-the-south. Fault G "dies out" in the deep-water shales of the Oligocene.

6) Thinning of beds over the crest of the structure and thickening of strata on the downthrown sides of fault A and C. The

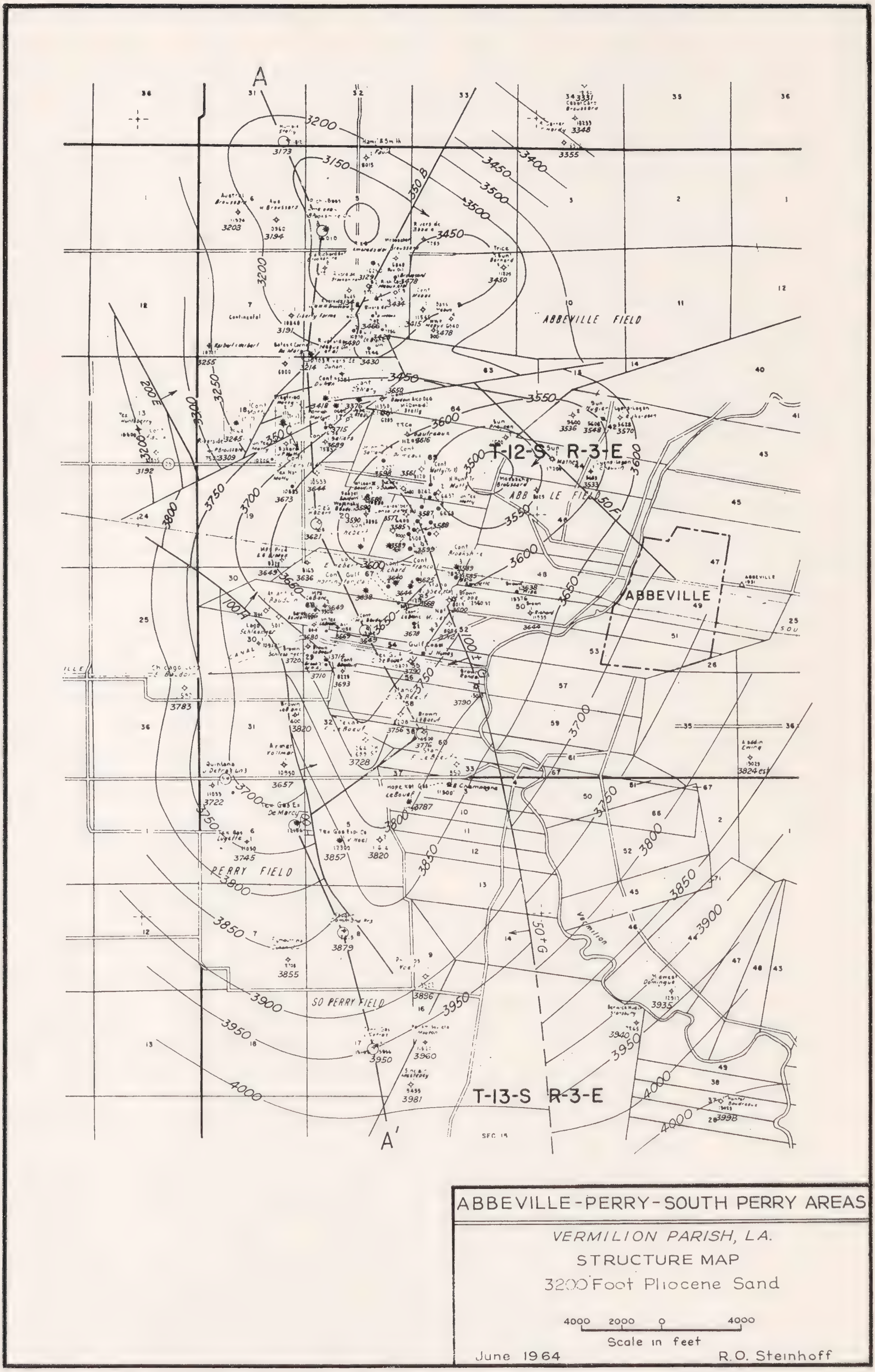

A
A'
3200
3150
3250
3300
3350
3400
3450
3500
3550
3600
3650
3700
3750
3800
3850
3900
3950
4000
ABBEVILLE FIELD
ABBEVILLE
PERRY FIELD
SO PERRY FIELD
T-12-S R-3-E
T-13-S R-3-E
ABBEVILLE-PERRY-SOUTH PERRY AREAS
VERMILION PARISH, LA.
STRUCTURE MAP
3200 Foot Pliocene Sand
4000 2000 0 4000
Scale in feet
June 1964
R.O. Steinhoff

PLATE III

thinning is especially marked in the southern portion of Abbeville field just south of fault C. The thinning and thickening are greatest in early Miocene and Oligocene beds above and along the hinge line surface.

7) Reverse dip and northward thickening of beds into the downthrown side of fault C. This phenomenon is greatest in Lower Miocene and *Planulina* beds.

8) Productive sands marked by the appropriate oil, gas, or gas-condensate symbols. Most of the productive reservoirs occur above the hinge line in neritic sands of Lower Miocene age. Productive sands in the bathyal facies below the hinge line occur in the Tennessee Gas No. 1 Detraz (South Perry field) and in the Richardson and Bass-Amerada No. 1 Brookshire (Abbeville field).

V. Occurrence of Productive Sands

The sands that produce oil, gas, or gas-condensate in the Abbeville-Perry-South Perry area are shown on the type logs (plate I). Total productive sands number 16 in Abbeville field, 3 in Perry field, and 1 in South Perry field. The most prolific reservoir sands occur above the hinge line surface and are confined to the continental-shelf facies of alternating sands and shales of Lower Miocene age. Only three sands have proven to be productive in the bathyal-type facies underlying the hinge line surface. Several thin productive sands occur in the massive sand facies of the Miocene and Pliocene.

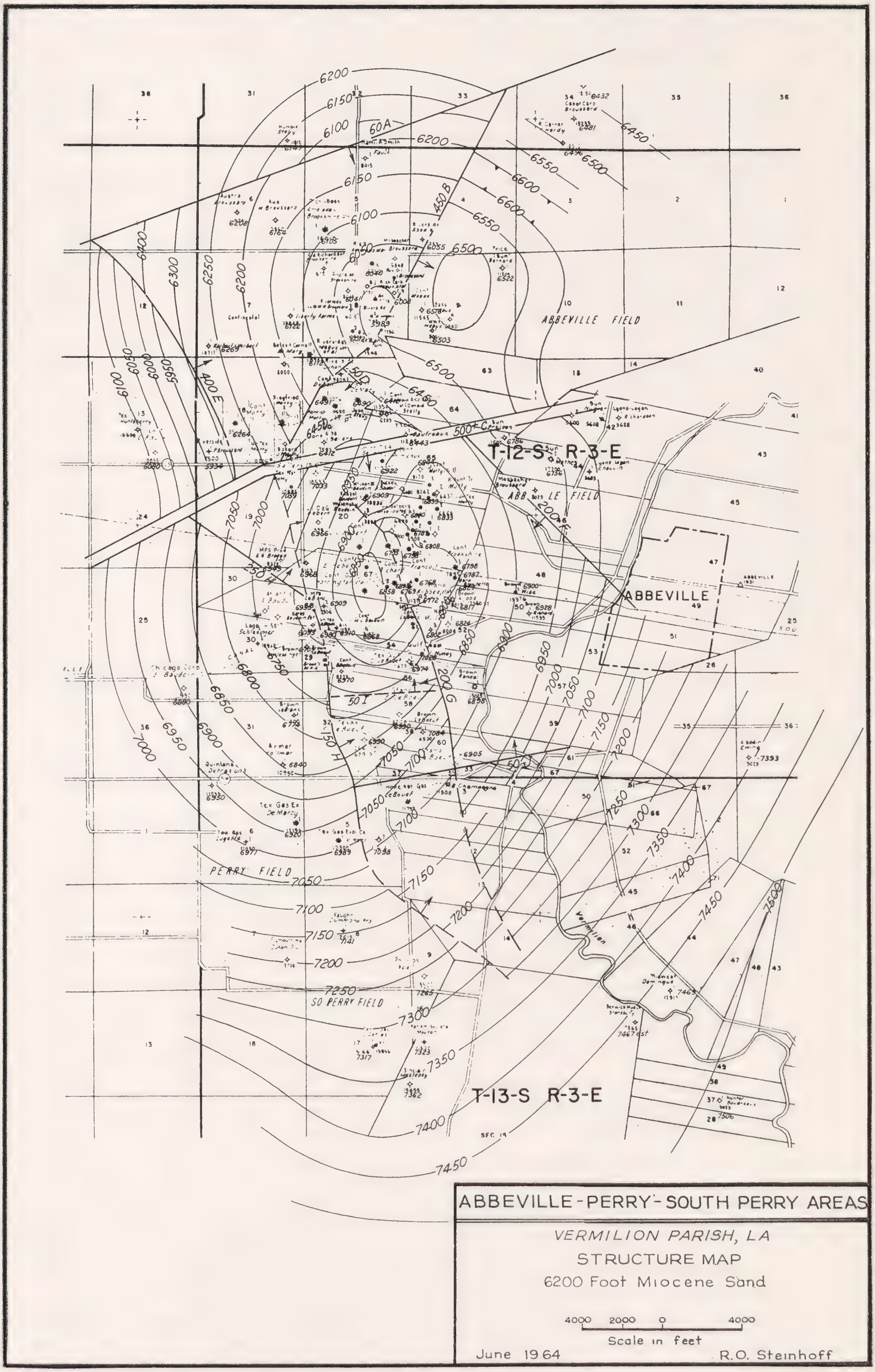
Three wells in the Abbeville-Perry-South Perry area have encountered productive sands in the bathyal facies of the Abbeville and Anahuac. In Abbeville field, the Richardson and Bass-Amerada No. 1 Brookshire (sec. 8, T12S, R3E) produces from a thin 15-foot gas-condensate sand in the Anahuac at a depth of 14,980 feet (see plate VIII). The Brown No. 1 LeBouef (sec. 29, T12S, R3E) was completed as a gas well in 16 net feet of sand in the Anahuac at a depth of 13,182 feet. The producing sand in the Tennessee Gas No. 1 Detraz, the discovery well for South Perry field, is a 36-foot gas sand at a depth of 14,712 feet (see plate VIII). The reservoir in the Detraz well is in the Abbeville Zone and is by far the most important of the productive sands encountered in bathyal-type sediments. The bathyal productive sands in Abbeville field are thin and erratic in nature. The reservoir sand in South Perry field may also be erratic in nature. This conclusion is based on the fact that the Sinclair Oil and Gas Company No. 1 Mestepey (the only other well drilled deep enough to encounter the producing sand in the South Perry field) found the reservoir sand in the Detraz No. 1 "shaled-out." This "shale-out," along with the lack of faulting on the producing-sand horizon, suggests that the trap at South Perry is stratigraphic. This suggestion, however, is based on very scant well control. Additional deep tests in the area may prove that the trap is due to deeply buried faulting.

Prolific Lower Miocene producing sands are present along the faulted crest of the Abbeville structure. Production from these sands is from both the upthrown and downthrown sides of fault C. Many of the wells on the north side of fault C penetrated multiple reservoir sands. For example, the Continental No. 1 DeMary (sec. 17, T12S, R3E) encountered four productive sands: a 65-foot gas sand at 9,628 feet, a 30-foot oil sand at 10,294 feet, a 45-foot gas sand at 10,512 feet, and a 23-foot gas sand at 10,583 feet. Wells with multiple-productive early Miocene sands also occur south of fault C. The Continental Oil Company No. 1 Wise Unit 4 (sec. 67, T12S, R3E) is typical of the wells producing on the downthrown side of fault C. In the zone from 10,600 feet to 11,300 feet, the Wise well penetrated four reservoirs that total over 180 net feet of productive sand. The uppermost reservoir at 10,608 feet in the Wise well occurs in several other wells and is one of the main producing sands on the downthrown side of fault C.

Several wells produce in Abbeville field from a 20- to 30-foot oil sand at the top of the *Amphistegina* "B" Zone. This is the only productive sand noted in this interval. There is no production from the *Amphistegina* "B" Zone north of fault C.

There are several productive sands above the *Amphistegina* "B" Zone in Abbeville field south of fault C. The sands occur mainly in the massive sand facies of the Miocene in the interval from 5,500 to 7,800 feet. Most of these shallow reservoirs have less than 20 net feet of productive sand.

The shallowest production in the area occurs in Abbeville field in the MacLean No. 1 Baudoin (sec. 20, T12S, R3E). Produc-



ABBEVILLE-PERRY-SOUTH PERRY AREAS

VERMILION PARISH, LA

STRUCTURE MAP

6200 Foot Miocene Sand

4000 2000 0 4000

Scale in feet

June 1964 R.O. Steinhoff

PLATE IV

tion is from 10 net feet of Pliocene oil sand at a depth of 3,850 feet on the downthrown side of fault C. The deepest test in the area, the Sun No. 1 Mailbes (sec. 44, T12S, R3E), also south of fault C, produces from 28 net feet of gas sand at the top of a thick Miocene sand body at a depth of 5,472 feet.

The two productive sands in Perry field are in the neritic sediments of the Lower Miocene (see plate VIII). The main reservoir, a 50-foot gas sand at approximately 10,900 feet, produces from two wells, the Texas Gas No. 1 DeMarcy and the Texas Gas No. 1 Noel. The reservoir is "shaled-out" in all surrounding wells except in the Texas Gas No. 1 Luquette (sec. 6, T13S, R3E). The Luquette well encountered the sand well-developed but dry. The sand was encountered 154 feet lower in the Luquette well than in the nearest producing well, The Texas Gas No. 1 DeMarcy. The other producing reservoir in Perry field, the 20-foot gas sand at a depth of approximately 11,200 feet in the Hope Natural Gas Company's No. 1 LeBouef and No. 1 Champagne, is erratic and is "shaled-out" in most surrounding wells. Production from this sand is confined to the upthrown side of fault G.

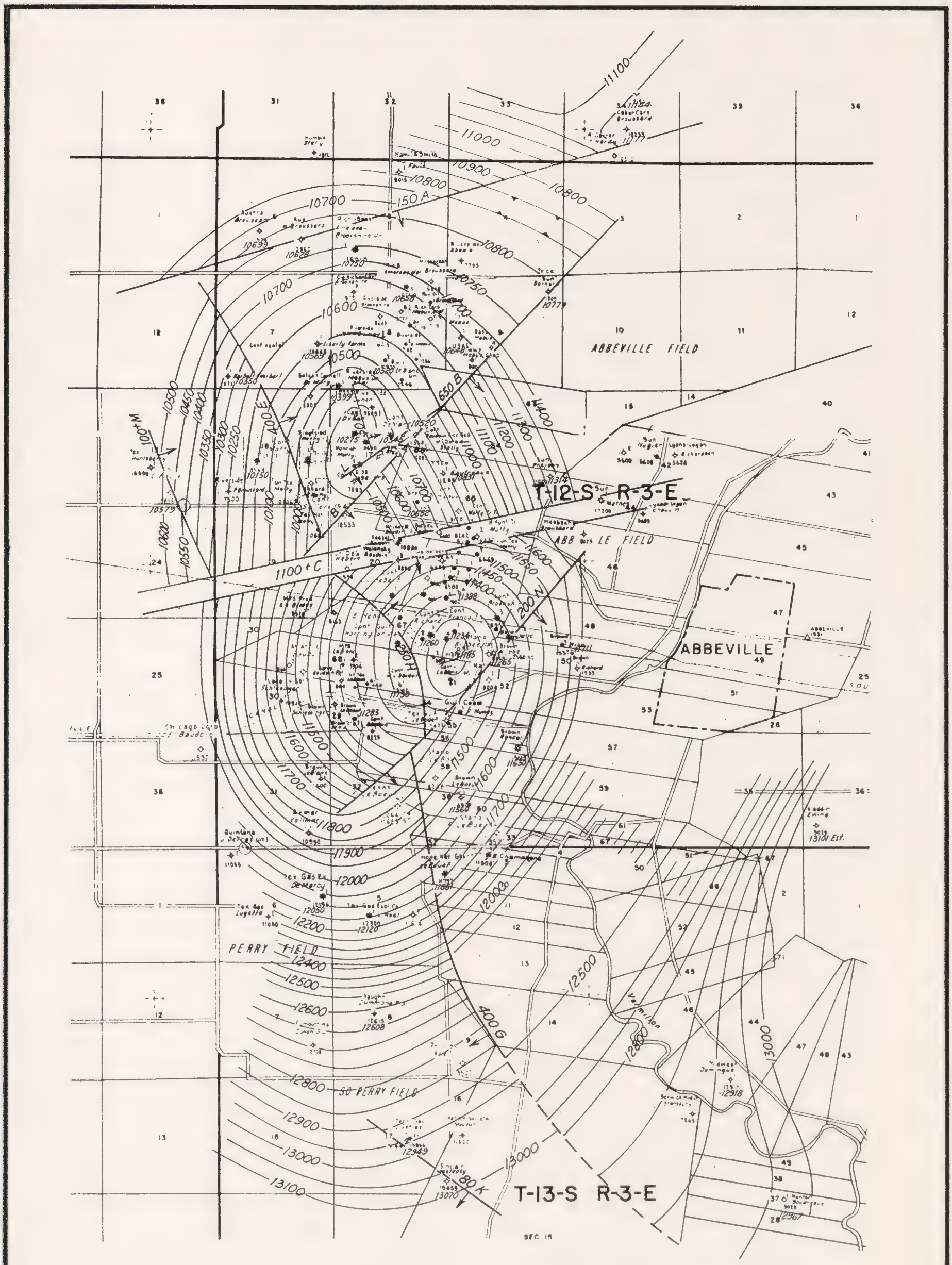
The most important fault affecting the accumulation of petroleum in Abbeville field is fault C. However, most of the productive sands in the Lower Miocene produce from both sides of fault C, suggesting that hydrocarbon migration took place before or during the development of fault C. Migration into the shallower Miocene sands productive only on the north side of fault C also took place before or during the development of fault C. Migration of hydrocarbons into sands that produce only on the downthrown side of fault C occurred after these sands had been deposited on the south side of fault C.

VI. Structural Growth and Geologic History

Thickening of beds onto the downthrown sides of faults and thinning of strata along the crest and over the structurally highest portions of the Abbeville-Perry-South Perry anticline were observed on all of the isopachous maps. These phenomena indicate that fault movement and anticlinal folding were contemporaneous with sedimentation and acted more or less continuously from the Oligocene into the Pliocene Epoch. The amount of such thickening or thinning of beds generally increases with depth, indicating that the greatest fault movement and anticlinal folding occurred early in the geologic history of the structure and decreased in magnitude with time. Thus, the greatest structural growth took place on the continental slope and outer continental shelf during late Oligocene and early Miocene time and was associated with the unstable conditions created by the hinge line environment. As the hinge line zone migrated seaward, faulting and anticlinal folding continued during the deposition of Miocene and Pliocene sediments but at a steadily reduced rate.

During Oligocene and early Miocene time the Abbeville-Perry-South Perry structure was positioned near the edge of the continental shelf. The oldest sediments penetrated by the drill are the Oligocene continental-slope deposits of the *Marginulina* Zone of the Anahuac Formation. *Marginulina* strata have been encountered only on the upthrown side of fault C. Wells to the south have not been drilled deep enough to encounter these deeper water sediments. During the time of deposition of the sediments in the *Marginulina* Zone, the Abbeville-Perry-South Perry structure was located on the continental slope. The continental-shelf deposits of the *Discorbis* Zone and *Heterostegina* Zone of the Anahuac Formation are confined to the upthrown side of fault C. The thick continental slope shales of the Abbeville represent the deeper-water equivalent of the *Discorbis* and *Heterostegina* intervals south of fault C. During the deposition of the sediments in the *Discorbis, Heterostegina,* and *Abbeville* zones, the Abbeville-Perry-South Perry anticline was positioned, first on the continental slope, and then on the continental shelf. The predominantly continental-shelf beds of the *Planulina* Zone (early Miocene) were deposited across both sides of fault C. The basal portion of the *Planulina* Zone south of fault C probably represents continental slope deposition. Thus, during the deposition of the *Planulina* Zone, the Abbeville-Perry-South Perry structure was situated near the shelf edge on the continental slope and later entirely on the continental shelf.

As the hinge line migrated seaward, the Abbeville-Perry-South Perry structure became positioned progressively closer to the shoreline. During Miocene time the



ABBEVILLE-PERRY-SOUTH PERRY AREAS

VERMILION PARISH, LA.

STRUCTURE MAP

Top of Planulina Zone

4000 2000 0 4000

Scale in feet

June 1964 R.O. Steinhoff

PLATE V

structure was located first, on the outer continental shelf, then on the intermediate continental shelf, and later on the inner continental shelf. During Pliocene time the structure was located in a near-shore or continental environment.

Fault C played a dominating role in the structural development of the Abbeville-Perry-South Perry structure. Continued movement along fault C, especially in late Oligocene and early Miocene time, kept the area south of fault C structurally lower than the area to the north, allowing greater thicknesses of sediments to accumulate on the downthrown side. The equivalent sediments on the upthrown side are much thinner.

Movement along faults F, G, and H also was contemporaneous with sedimentation. Thickening of beds is especially prominent in the graben formed by faults F, H, and G (see plate VI). Although fault F and portions of faults B and H developed during the deposition of the Anahuac, the graben did not begin to form until early Miocene time. Movement along faults A and B generally took place after the deposition of the sediments. No noticeable change in thickness across fault A can be detected in beds of Miocene and Pliocene age. Since there is no deep-well control north of fault A, the amount of thickening (if it does occur) of the Anahuac across fault A is not known. The lack of thickening onto the downthrown side of fault B on plate VII suggests that fault B originated after the Anahuac and Lower Miocene beds had been deposited.

Comparison of the various structural maps shows that the Abbeville-Perry-South Perry structure increases in sharpness with depth. In fact, the anticline mapped on the deepest mapping horizon (top of the *Planulina* Zone) is quite narrow. The structure could not continue to increase in sharpness through thousands of feet of sediments to some deep-seated origin. The writer believes that this structure had its beginning with anticlinal folding and faulting that originated on the continental slope near the shelf edge during late Oligocene time.

VII. Summary and Conclusions

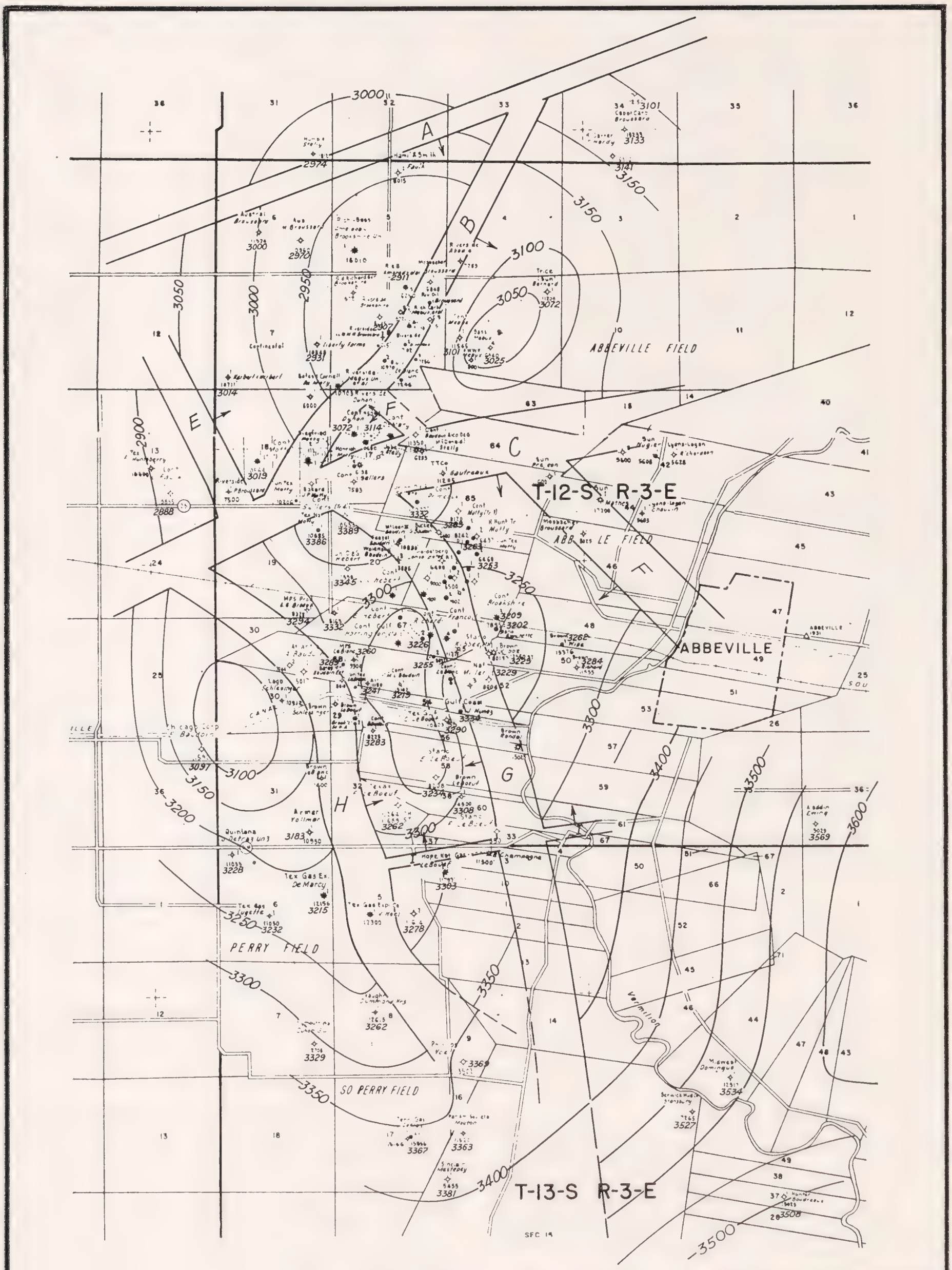
(1) Strata in the Abbeville, Perry, and South Perry fields range from Pliocene to Oligocene in age. Wells drilled to sufficient depth in these fields encounter three distinct facies: first, a shallow-water massive Pliocene and Miocene near-shore to continental sand facies; then, an intermediate facies of alternating sand and shales from the Miocene continental shelf; and, finally, the thick deep-water shale facies of the early Miocene and late Oligocene.

(2) Structurally, the Abbeville-Perry-South Perry feature is a faulted, north-northwest trending anticline elongated for several miles normal to the regional strike of the beds. All faults are normal and include both down-to-the-basin and up-to-the-south faults. The main faults are down-to-the-basin, regional in nature, and trend parallel to the regional strike of the beds. The smaller faults are compensating up-to-the-south faults confined to the Abbeville-Perry-South Perry structure. The throw generally increases gradually with depth. The several faults with throw decreasing with depth appear to "die-out" in the deep-water shale facies of the Anahuac Formation and the Abbeville Zone.

(3) Beds are thin along the crest of the structure and thicken on the downthrown sides of the faults. The amount of thinning or thickening generally increases gradually with depth. Thus, anticlinal folding and fault movement occurred contemporaneous with sedimentation, acted more or less continuously from Oligocene into Pliocene time, and were greatest in intensity during Oligocene and Lower Miocene time.

(4) The Abbeville-Perry-South Perry structure originated with anticlinal folding and faulting near the shelf edge during Oligocene and early Miocene time. As the hinge line migrated basinward, the structure became positioned progressively closer to the shoreline until, in Pliocene time, it was near the shoreline. Anticlinal folding and fault activity were greatest when the structure was located near the shelf edge. Structural activity steadily decreased as the hinge line with its unstable environment continued to migrate southward.

(5) The most prolific reservoir sands are in the continental-shelf facies of alternating sands and shales. The few productive sands that occur in the bathyal facies are thin and erratic. Producing intervals encountered in the massive sand facies are generally thin and relatively unimportant.



ABBEVILLE - PERRY - SOUTH PERRY AREAS

VERMILION PARISH, LA.

ISOPACHOUS MAP

3200-Foot, Pliocene - 6200 Foot Miocene Interval

4000 2000 0 4000

Scale in feet

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PLATE VI

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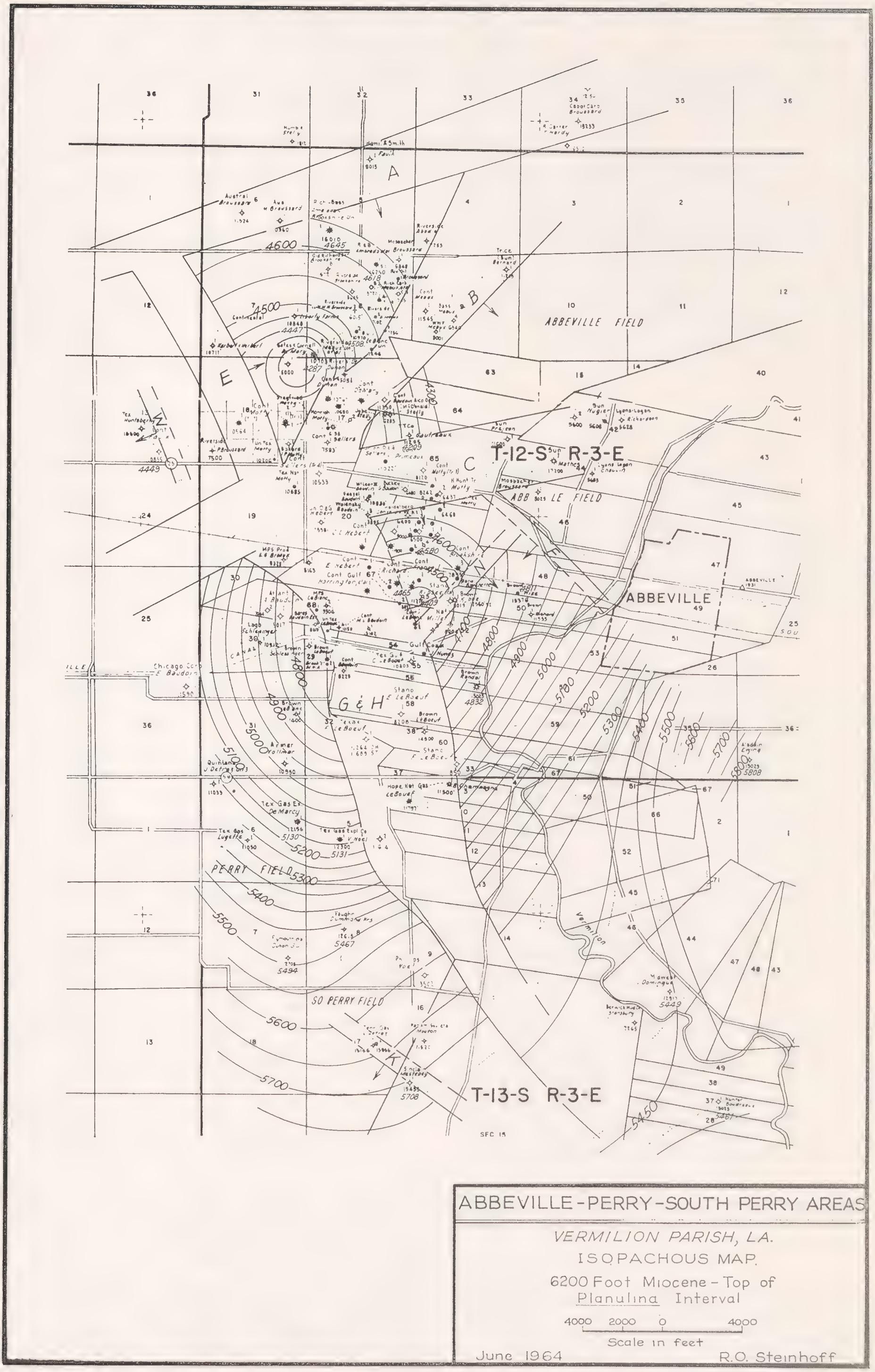

ABBEVILLE-PERRY-SOUTH PERRY AREAS

VERMILION PARISH, LA.

ISOPACHOUS MAP.

6200 Foot Miocene - Top of Planulina Interval

4000 2000 0 4000

Scale in feet

June 1964 R.O. Steinhoff

PLATE VII

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ERRATA

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NO. 3—pages 104 and 106. The scales at the bottom of figures 1 and 2 were inadvertently omitted by the engraver. The complete corrected figures are reproduced below. (continued on page 148)

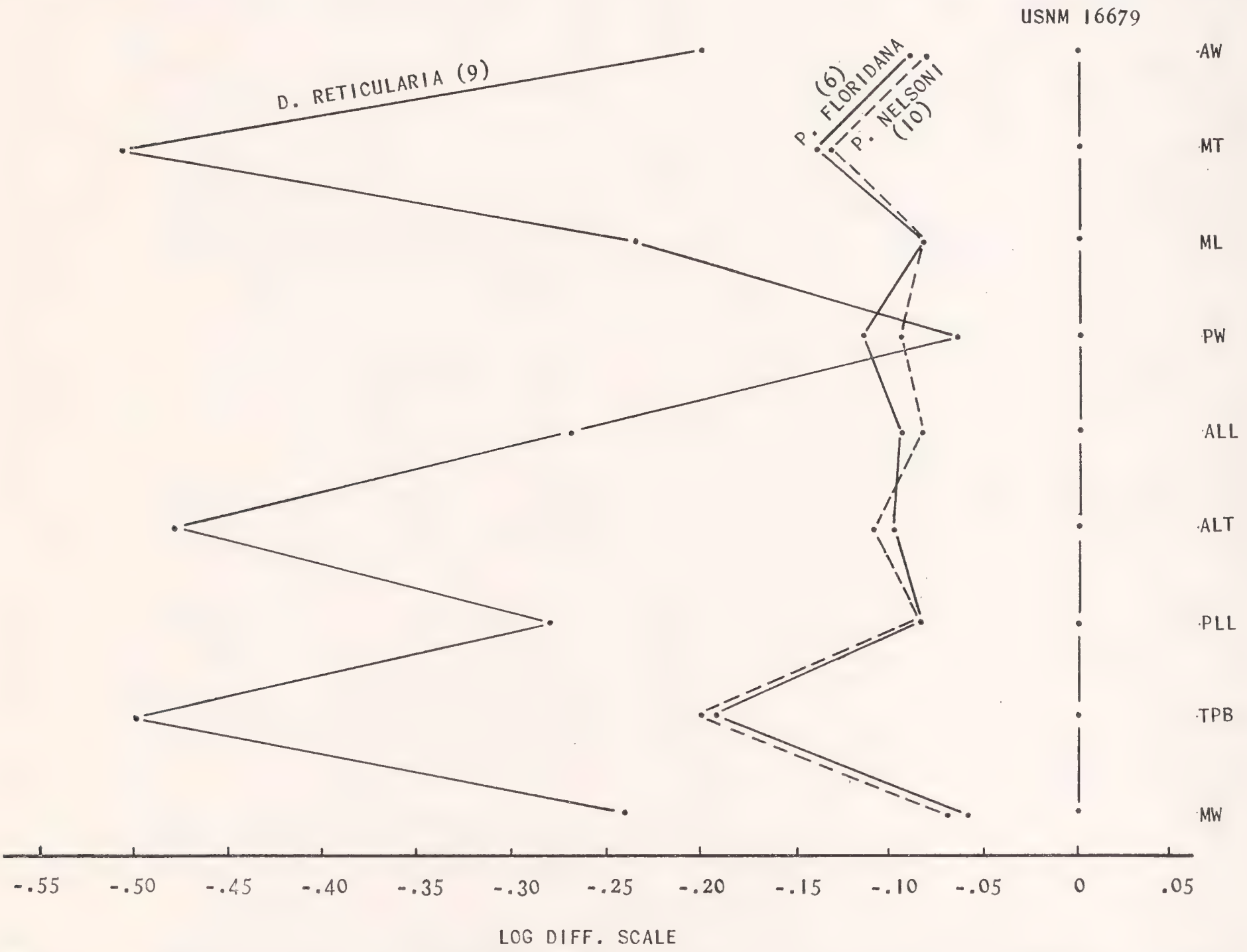

Figure 1. Ratio diagram of dimensions of nuchal bone in several turtles, as labeled. USNM 16679 is the holotype of *D. floridana*. Numbers in parenthesis refer to number of specimens. A W = width of anterior border, M T = maximum midline thickness, M L = median length, P W = width of posterior border, A L L = length of anterolateral border, A L T = thickness of anterolateral border, P L L = length of posterolateral border, T P B = thickness of posterior border, M W = maximum width.

REVISION OF THE FORAMINIFERAL FAMILY PSEUDOPARRELLIDAE VOLOSHINOVA

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CONTENTS

Page

I. ABSTRACT 117

II. INTRODUCTION 117

III. REVISION OF THE PSEUDOPARRELLIDAE 118

IV. CALIFORNIA SPECIES 123

V. DESCRIPTION OF TYPE AND CALIFORNIA SPECIES 124

VI. REFERENCES 138

PLATE I. *Pseudoparrella* and *Ambitropus* 143

PLATE II. *Concavella, Epistominella,* and *Stetsonia* 145

PLATE III. *Megastomella* and *Eilohedra* 147

I. ABSTRACT

The Pseudoparrellidae Voloshinova, 1952, is recognized as a distinct family of the Discorbacea (Foraminiferida) on the basis of trochospiral tests, hyaline calcite walls with radial crystalline structure, monolamellid septa and a vertical aperture parallel to the periphery of the test. As redefined, the family contains six genera: *Pseudoparrella* Cushman and ten Dam, *Epistominella* Husezima and Maruhasi, *Megastomella* Faulkner, de Klasz and Rérat, *Stetsonia* F. L. Parker, *Concavella* Lipps, gen. nov. (type species *Pulvinulinella gyroidinaformis* Cushman and Goudkoff), and *Ambitropus* Lipps, gen. nov. (type species *Epistominella evax* Bandy). Species of the Pseudoparrellidae occur in Oligocene? to Recent deposits throughout the world.

Nineteen species and two varieties of foraminifera have been recorded from California as Pseudoparrellidae. Thirteen of these are considered valid and represent five of the six genera of Pseudoparrellidae. A new genus, *Eilohedra* (type species *Epistominella levicula* Resig), is erected in the Eponididae to contain species superficially similar to pseudoparrellids but differing in the bilamellid wall structure.

II. INTRODUCTION

The foraminiferal family Pseudoparrellidae Voloshinova, 1952, has been recognized as a distinct category only by Soviet paleontologists. Other workers have assigned the genera included herein to superficially similar families such as the Cassidulinidae (Cushman, 1948), the Discorbidae (Glaessner, 1945; Loeblich and Tappan, 1964), or less frequently to other groups. However, the genera recognized in this report as Pseudoparrellidae have characters in common which distinguish them from all other groups of foraminifera.

Procedure: Primary types and, where possible, topotype and other material were studied to ascertain the range of variability for each species. Specific limits were established using several hundred specimens from various localities. The species were then

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grouped into genera. These genera were defined on the basis of external morphology and microstructure of the type species (or when material for the type species was inadequate, other similar species were utilized). The microstructure of the test wall was studied in thin section using transmitted and polarized light with magnifications up to 1000.

Acknowledgments: This study was initiated and partially completed while I was at California Research Corporation, La Habra, during the summer of 1963. The Corporation provided financial assistance, the use of the laboratory facilities and help in the preparation of the manuscript. Drs. A. R. Loeblich and Helen Tappan Loeblich assisted in the field, helped to obtain specimens, allowed use of their extensive library of Russian literature, and critically read the manuscript. The following people donated specimens utilized in this study: F. L. Parker and M. N. Bramlette, Scripps Institution of Oceanography, La Jolla, California; K. Asano, Tohoku University, Sendai, Japan; R. L. Pierce, Bakersfield, California. Mr. L. E. Garrison, Sacramento, California, deposited all type specimens established by him in 1959 in the Type Collections, Geology Dept., University of California, Los Angeles. James C. Ingle, University of Southern California, and Richard Cifelli, U. S. National Museum, loaned type material for study from their institutions.

III. Revision of the Pseudoparrellidae

Superfamily Discorbacea Ehrenberg, 1838
Family Pseudoparrellidae Voloshinova, 1952

Family Pseudoparrellidae Subbotina, 1959, *in* Rauzer-Chernousova and Fursenko, 1959, Osnovy Paleontologii, v. 1, p. 272 *(partim)*. [*nom. correct.* and *nom. transl. ex.* subfamily Pseudoparellinae Voloshinova, 1952.]

Subfamily Pseudoparellinae Voloshinova *in* Voloshinova and Dain, 1952, Trudy VNIGRI, nov. ser., vyp. 63, p. 81.

Subfamily Epistominellinae Reiss, 1963, Geol. Surv. Israel Bull. 35, p. 54 *(partim)*.

Type genus: *Pseudoparrella* Cushman and ten Dam, 1948, Contr. Cushman Lab. Foram. Res., vol. 24, pt. 3, p. 49.

Description: Test free, trochospiral or initially trochospiral, biconvex to convex on one side only. Wall calcareous, hyaline, perforate, crystal structure radial, septa monolamellid. Aperture a vertical slit in face of last chamber, parallel to periphery of test, basal, may tend to become areal.

Discussion: The family Pseudoparrellidae was defined originally on external morphology as a subfamily of the Cassidulinidae (see Voloshinova, 1952, p. 81). A close relation between *Pseudoparrella* and *Cassidulina* was first suggested by Cushman (1926) when he established *Pulvinulinella* [=*Pseudoparrella*]. In describing the genus Cushman reported an "apertural tooth" projecting from the side of the aperture, similar to that of *Cassidulina.* The type species, *Pseudoparrella subperuviana* (Cushman) and other Recent Pacific species have a straight or slightly bent apertural slit extending up the face of the last chamber, but no projecting tooth. Reiss (1963, p. 54) believed the "Cassidulinid toothplate" (in the sense of Hofker, 1951), described by Haynes (1956) and Hofker (1957) for species of so-called *Pseudoparrella,* also indicated a close relationship to the Cassidulinidae. However, Holker's (1957, p. 382) figures of *Pseudoparrella toulmani* (Brotzen) distinctly show a low interiomarginal aperture extending along the basal suture of the last chamber from near the umbilicus to near the periphery. Hofker's specimens are therefore not true *Pseudoparrella.* Haynes (1956, p. 88) described internal toothplates extending between succeeding apertures in Paleocene specimens, identified as *Epistominella vitrea* Parker [=*Pseudoparrella vitrea*]. He described and figured a loop-shaped aperture although *P. vitrea,* described from Recent sediments, has a typical *Pseudoparrella* slit-like aperture parallel to the periphery (Parker *in* Parker, Phleger and Peirson, 1953, p. 9). Haynes' specimens belong to another genus and species. Neither the type nor other species of *Pseudoparrella* have toothplates which extend from a former aperture to the next. The apertures are folded inward slightly around the entire margin. Although Hofker (1951) attaches great importance to these and similar structures ("toothplates" or their "homologous" parts), the function in the living animal is unknown and thus the biologic significance remains uncertain. Apertural modifications such as those in the Pseudoparrellidae probably serve to strengthen the apertural opening mechanically.

Reiss (1963) considered the Epistominellinae [=Pseudoparrellidae] closely related to the cassidulinids and placed his sub-

family in the Cassidulinidae. He placed little importance on the crystal structure of the test wall, but instead relied on the lamellar character of the septa as indicative of true relations. Hence, he grouped monolamellid, radial forms with the monolamellid, granular cassidulinids. However, as crystal structure of the test wall appears to be of primary significance in the determination of natural groups of foraminifera (Loeblich and Tappan, 1964, p. C153), the radial-walled Pseudoparrellidae are not closely related to the granular-walled Cassidulinidae. Thus there is neither gross nor microstructural evidence for relating the Pseudoparrellidae to the Cassidulinidae.

Loeblich and Tappan (1961, p. 316) placed the Pseudoparrellinae in synonymy with the granular-walled Alabaminidae, but later (1964, p. C572) recognized the true radial-walled construction of the nominal genus, and placed the subfamily in synonymy with the Discorbinae.

Reiss (1963, p. 54) proposed the subfamily Epistominellinae as a new name for Pseudoparrellinae Voloshinova, as the genus *Epistominella* was considered a senior synonym of *Pseudoparrella.* This name is invalid because after 1960 a family-group name based on a junior synonym "is not to be changed, but continues to be the valid name of the family-group taxon that contains both the senior and junior synonyms" (Internat. Code of Zoological Nomenclature, art. 40). Furthermore, both *Pseudoparrella* and *Epistominella* are shown to be distinct and valid genera.

The Pseudoparrellidae is recognized as a distinct family on the basis of its radially-built, hyaline calcite walls, monolamellid septa, and aperture parallel to the periphery of the test, extending up the face of the last chamber.

Distribution: Pseudoparrellidae are known from the Oligocene (questionably) to the Recent (Figure 1) although they have been reported from rocks as old as Early Cretaceous (Kaptarenko-Chernousova, 1959). All species in Ellis and Messina (1940, *et seq.*) and most species from Soviet literature included in genera of Pseudoparrellidae were evaluated. All species older than Oligocene were assignable to other families. Some very similar, but still questionable species were described from Oligocene rocks. Species definitely known to belong to this family are Miocene or younger; older records should be critically re-examined.

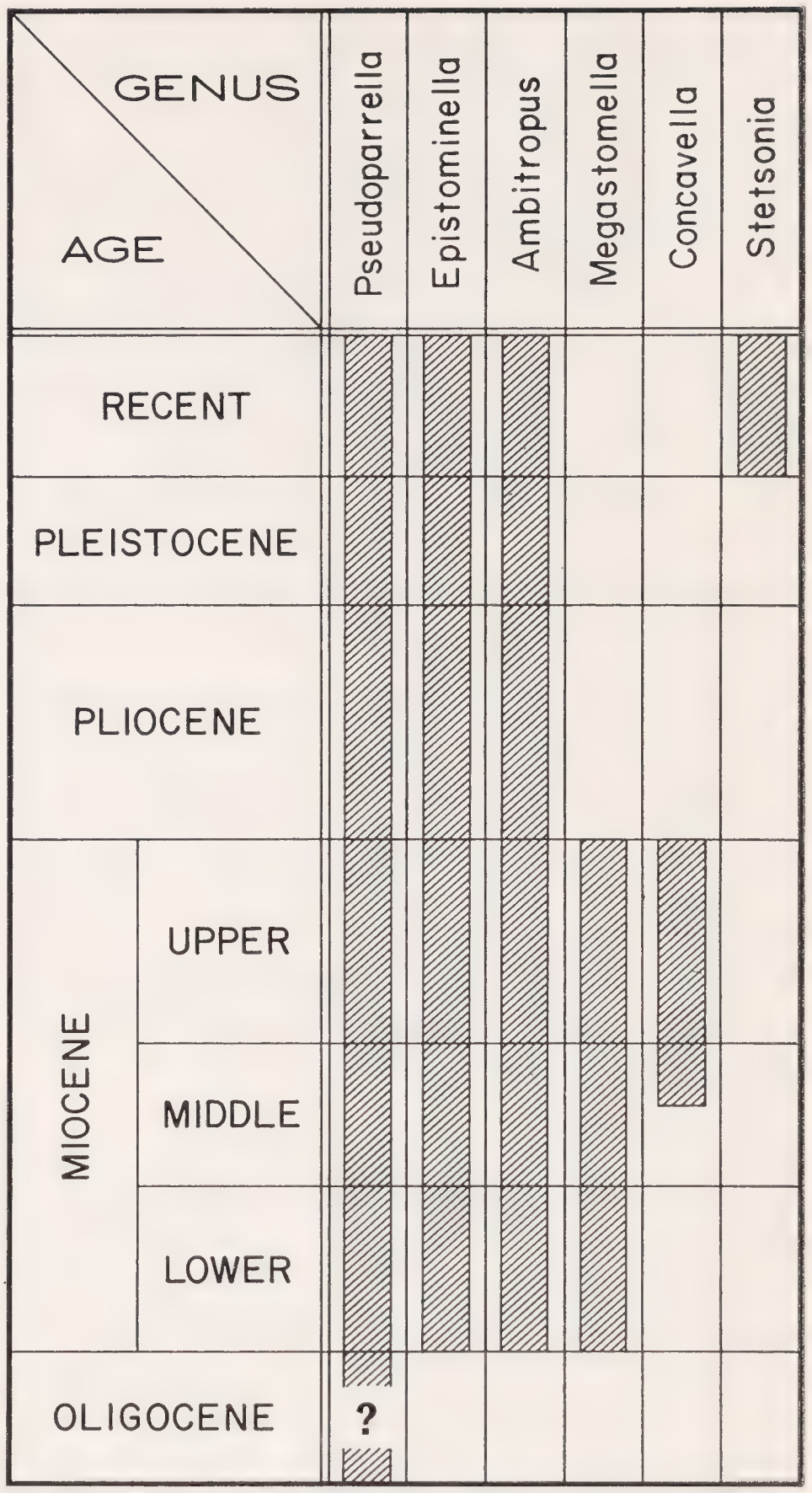

Figure 1. Stratigraphic distribution of the genera of Pseudoparrellidae.

The Pseudoparrellidae generally are found in deeper water on fine-grained substrates throughout the world. Many species have restricted geographic distributions while others, such as *Pseudoparrella exigua* (Brady), are apparently distributed in deep water throughout the world.

Genera: The Pseudoparrellidae, as originally defined (Voloshinova, 1952), contained only the genus *Pseudoparrella,* but some of the species then included are correctly referred to *Epistominella* and *Osangularia* Brotzen. On the basis of external morphology, Subbotina (*in* Rauser-Chernousova and Fursenko, 1959, p. 272) also included therein the genera *Pseudoparrella, Alabamina* Toulmin and *Cribroparrella* ten Dam. Reiss (1963, p. 54) placed *Epistominella* and

Coleites Plummer in the Epistominellinae [=Pseudoparrellidae]. However, *Osangularia, Alabamina, Cribroparrella,* and *Coleites* have granular walls (see Loeblich and Tappan, 1964) and must be excluded from the Pseudoparrellidae.

As redefined, six genera, two of which are new, comprise the Pseudoparrellidae. These genera and their type species are herein redescribed and illustrated.

Genus PSEUDOPARRELLA Cushman and ten Dam, 1948

Pseudoparrella CUSHMAN and TEN DAM, 1948, Contr. Cushman Lab. Foram. Res., vol. 24, pt. 3, p. 49.

Pulvinulinella CUSHMAN, 1926, Contr. Cushman Lab. Foram. Res., vol. 2, pt. 3, p. 62 (NOT *Pulvinulinella* Eimer and Fickert, 1899).

Pseudoparella VOLOSHINOVA, *in* VOLOSHINOVA and DAIN, 1952, Trudy VNIGRI, nov. ser., vyp. 63, p. 81.

Type species: *Pulvinulinella subperuviana* Cushman, 1926. Fixed by original designation and monotypy.

Description: Test free, small to medium in size, trochospiral, biconvex, outline nearly circular to slightly oval, slightly or not umbilicate, tightly coiled. Chambers rhomboid or nearly so, all visible from spiral side, only those of last formed whorl visible from umbilical side. Periphery sharp to rounded, unkeeled. Sutures radial or slightly curved on umbilical side, directed backward on spiral side. Wall calcareous, radially-built, monolamellid septa, finely perforate. Aperture a narrow basal slit extending up the face of the last chamber, parallel to periphery of test, on umbilical side, bordered by a slight lip which curves inward.

Discussion: This genus differs from other genera of Pseudoparrellidae in having a biconvex test, nearly circular outline, rhomboid-shaped chambers on the spiral side, and in lacking a peripheral keel. *Pseudoparrella* is similar to *Megastomella;* their distinguishing characters are listed below:

Pseudoparrella

Test: biconvex
Chambers: increasing slowly in height with growth; rhomboid in spiral view.
Outline: circular
Aperture: on umbilical side; narrow

Megastomella

Test: flattened; concave on umbilical side.
Chambers: increasing rapidly in height with growth; elongate in spiral view.
Outline: oval
Aperture: peripheral to slightly on umbilical side; wide in mature individuals.

Pseudoparrella has been regarded as a synonym of *Epistominella* Husezima and Maruhasi, 1944. The similarity between the two was recognized by Husezima and Maruhasi (1944, p. 397) when they established *Epistominella.* However, the lack of a peripheral keel, the biconvexity of the test, and the straight, rather than sharply bent aperture of *Epistominella,* are sufficient to distinguish *Pseudoparrella* as a separate genus.

Pseudoparrella is known from all parts of the world in Miocene to Recent deposits and may also occur in Oligocene rocks.

Genus AMBITROPUS Lipps, gen. nov.

Type species: *Epistominella evax* Bandy, 1953, Jour. Paleontology, vol. 27, no. 2, p. 179, pl. 23, figs. 1a-c.

Description: Test free, trochospiral, flattened with the spiral side about equally as convex as the umbilical side, periphery keeled, keel bifurcating around aperture. Chambers generally crescent-shaped, increasing rapidly in size in later stages giving test an oval outline. Wall calcareous, smooth, perforate, crystalline structure radial, septa monolamellid. Aperture basal, a long, wide opening in periphery of last chamber.

Discussion: Ambitropus differs from other Pseudoparrellidae in its peripheral aperture and keel. *Epistominella* is most similar but its aperture is always on the umbilical side of the test and is slightly bent, and its test is more nearly circular in outline. Other genera with peripheral apertures, *Megastomella* and *Stetsonia,* are never carinate.

Species assigned to this genus range from early Miocene to Recent in age and have been found only in the Eastern Pacific Ocean or adjacent fossil deposits. *Ambitropus evax* (Bandy) was described from Recent sediments off San Francisco and *A. thalmanni*

TABLE 1
Key to the Genera of Pseudoparrellidae

1.	a.	Peripheral keel present	2
	b.	Peripheral keel absent	4
2.	a.	Aperture on umbilical side (1a)	3
	b.	Aperture peripheral (1a)	*Ambitropus*
3.	a.	Spiral side strongly concave (2a)	*Concavella*
	b.	Umbilical side strongly convex (2a)	*Epistominella*
4.	a.	Generally oval in outline, aperture peripheral (1b)	5
	b.	Generally circular in outline, aperture on umbilical side (1b)	*Pseudoparella*
5.	a.	Test distinctly trochospiral (4a)	*Megastomella*
	b.	Test nearly involute (4a)	*Stetsonia*

(Stainforth and Stevenson) was described from the Lower Miocene of Ecuador.

The generic name is from the Latin, *ambio, -itus,* meaning "around", and *tropis, -eos, -idos,* meaning "keel", referring to the peripheral keel around the entire test margin. Gender: Masculine.

Genus CONCAVELLA Lipps, gen. nov.

Type species: *Pulvinulinella gyroidinaformis* Cushman and Goudkoff, 1938, Contr. Cushman Lab. Foram. Res., vol. 14, pt. 1, p. 2, pl. 1, figs. 1a-2c.

Description: Test free, trochospiral, concavo-convex, spiral side concave in adult, umbilical side generally strongly convex, outline oval to circular, periphery broadly rounded, keeled at juncture with spiral side. Chambers inflated on umbilical side. Wall calcareous, hyaline, crystalline structure radial, septa monolamellid. Aperture basal or areal in larger specimens, a narrow slit in face of last chamber on umbilical side of test.

Discussion: This genus is distinguished by its concave spiral side, large broadly rounded chambers, a keel at the juncture of the spiral side and periphery, and a tendency for the aperture to become areal in large specimens. The early stages are similar to small specimens of *Epistominella,* but in later stages the typical characters of *Concavella* are developed.

This genus is monotypic. *Concavella gyroidinaformis* (Cushman and Goudkoff) is known from the Luisian and Mohnian Stages of California.

The generic name is from the Latin *concavus,* meaning hollowed or arched inward; +*-ella,* a diminutive. Gender: Feminine.

Genus EPISTOMINELLA Husezima and Maruhasi, 1944

Epistominella HUSEZIMA and MARUHASI, 1944, Jour. Sigenkagaku Kenkyusyo, vol. 1, no. 3, p. 397.

Type species: *Epistominella pulchella* Husezima and Maruhasi, 1944. Fixed by original designation and monotypy.

Description: Test free, small to medium in size, trochospiral, planoconvex, or with spiral side slightly convex, umbilical side strongly convex, periphery keeled. Chambers trigonal on umbilical side, rhomboid to lunate on spiral side. Wall calcareous, smooth, perforate, crystalline structure radial, septa monolamellid. Aperture basal, a narrow slit in face of last chamber, on umbilical side of test.

Discussion: This genus is differentiated by its peripheral keel, convex umbilical side, and nearly flat spiral side. The genus is similar to *Concavella* but does not have a keel on the spiral side of the periphery, large, broadly rounded chambers, nor a concave spiral side.

Species of *Epistominella* are abundant in the North Pacific Ocean basin and adjacent fossil deposits. Some fossil species also have been reported from the Mediterranean area. The genus is also reported from Recent deposits of the Arctic Ocean. *Epistominella* ranges from the early Miocene to Recent.

Genus MEGASTOMELLA Faulkner, de Klasz, and Rérat, 1963

Megastomella FAULKNER, DE KLASZ, and RÉRAT, 1963, Revue Micropaléontologie, vol. 6, no. 1, p. 19.

Type species: *Megastomella africana* Faulkner, de Klasz, and Rérat, 1963. Fixed by original designation.

Description: Test free, small to medium in size, trochospiral, flattened to slightly biconvex, outline oval, periphery broadly to sharply rounded. Chambers long, narrow, crescent-shaped, generally more than twice as high as wide. Sutures radial, depressed. Wall calcareous, smooth, perforate, crystalline structure radial, septa monolamellid. Aperture basal, a long wide slit in face of final chamber, generally peripheral or slightly on umbilical side of test.

Discussion: Megastomella differs from other genera in its wide, peripheral aperture, elongate chambers typically three times as high as wide, and non-carinate periphery. *Megastomella* resembles *Pseudoparrella* and their differing characters are listed in the discussion of *Pseudoparrella. Megastomella* differs from *Stetsonia* in being trochospiral throughout ontogeny.

The type species, *Megastomella africana,* was described from pyrite casts found in Africa (Faulkner, de Klasz, and Rérat, 1963). A single topotype, also a pyrite cast, given to A. R. Loeblich by de Klasz, is figured (Plate III, figures 3a-c). Because of the preservation, the characters of the test wall could not be determined for the type species. In the morphologically similar California species, *M. capitanensis* (Cushman and Kleinpell), the crystalline structure of the wall is radial and the septa are monolamellid.

The genus is known from the lower Miocene in Africa and the upper Miocene in

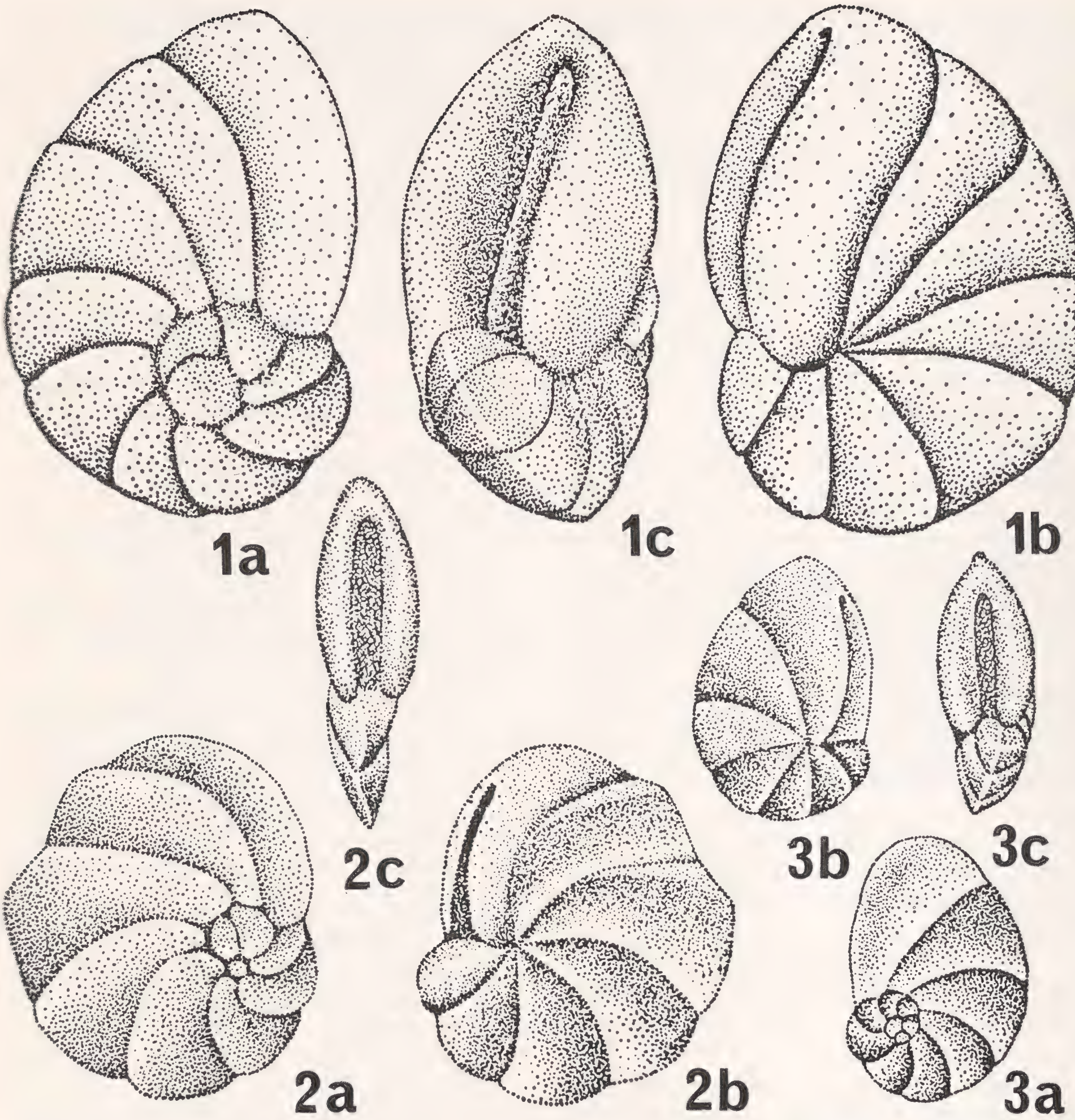

Figure 2. Variation in the type species of *Megastomella: M. africana.* 1. *Megastomella africana africana* Faulkner, de Klasz and Rérat, Holotype, Miocene, Gabon. 2 and 3. *M. africana compressa* Faulkner, de Klasz and Rérat, Miocene, Nigeria, Paratype (2) and Holotype (3). All figures X40, after Faulkner, de Klasz and Rérat, 1963.

California. It is generally found in fine-grained sediments.

Genus STETSONIA F. L. Parker, 1954

Stetsonia F. L. Parker, 1954, Mus. Comp. Zool., Harvard, Bull., vol. 111, no. 10, p. 534.

Type species: *Stetsonia minuta* F. L. Parker, 1954, Mus. Comp. Zool., Harvard, Bull., vol. 111, no. 10, p. 534, pl. 10, figs. 27-29. Fixed by original designation and monotypy.

Description: Test free, small, initially trochospiral, involute in later stages, biconvex, outline circular to oval, periphery broadly rounded. Chambers increasing in height with growth, crescent-shaped. Wall calcareous, smooth, finely perforate, crystalline structure radial, septa monolamellid. Aperture basal, a peripheral slit parallel to test margin or slightly to one side of periphery, in face of last chamber.

Discussion: This genus can be differentiated from other Pseudoparrellidae by its nearly planispiral test in the adult, and by the peripheral aperture.

Two species of *Stetsonia* have been described to date, the type species, *S. minuta,* from the Gulf of Mexico, and *S. horvathi* Green from the Arctic Ocean (Green, 1960).

This small genus is more abundant in

deeper water but also occurs in shallow water.

IV. California Species

Species of Pseudoparrellidae are common constituents of fossil and living foraminiferal faunas in the California region. Because the same or similar species are living today, many are useful paleoenvironmental indicators. Some extinct forms may be useful stratigraphic markers. Nineteen species and two varieties reported from California have been assigned to genera of the Pseudoparrellidae. Four of these species are not pseudoparrellids and four are synonymous with other species. The remaining thirteen species are considered valid and represent five of the six genera of Pseudoparrellidae. The species previously reported from California are summarized in Table 2, together with their specific and generic reassignment, and the valid species of Pseudoparrellidae from California are described below in section V.

Species erroneously reported as Pseudoparrellidae in California: The species from California reported incorrectly as Pseudoparrellidae are discussed below and excluded from the family.

Pulvinulinella culter: This species was recorded from the Eocene in Fresno County (Martin, 1943) and questionably from the lower Zemorrian in the Santa Cruz Mountains (Kleinpell, 1938, p. 327). Kleinpell's figure (1938, pl. 5, fig. 15) of the apertural view shows a small, wide, areal aperture unlike any Pseudoparrellidae but more closely resembling certain Ceratobuliminidae and Anomalinidae. The specimen is broken and positive identification is difficult. Martin's specimens were assigned to *Parrella* [=*Osangularia*] by Mallory (1959, p. 239).

Pulvinulinella cf. *P. danvillensis:* This designation was given a specimen figured from the Eocene Kreyenhagen Shale by Mallory (1959, p. 240). Mallory states that his specimen has a more rounded periphery than do the type specimens of the species. In addition the apertural position is quite distinct and unlike the holotype, which is an *Alabamina* (see Howe and Wallace, 1932, pl. 13, fig. 7). Unfortunately the last chambers of Mallory's specimen are broken away and generic identification is not possible. The aperture appears to extend vertically up the chamber face and has a projection similar to species of *Eponidella* Cushman and Hedberg.

Epistominella levicula: The generic position of this Recent Californian species has been uncertain in the past. It has been placed

Table 2

Summary and revised assignment of species reported from California as Pseudoparrellidae. Arranged alphabetically by reported specific designation. Species which are not Pseudoparrellidae are marked with an asterisk.

Reported generic assignment	Reported specific assignment from California	Revised generic and specific assignment
Pulvinulinella	bradyana	Pseudoparrella subperuviana
Pulvinulinella	capitanensis	Megastomella capitanensis
Pulvinulinella	culter	Osangularia culter*
Pseudoparrella	cf. P. danvillensis	genus and species undetermined*
Epistominella	discorbisoides	Pseudoparrella? discorbisoides
Epistominella	evax	Ambitropus evax
Pulvinulinella	exigua	Pseudoparrella exigua
Pulvinulinella	gyroidinaformis	Concavella gyroidinaformis
Epistominella	levicula	Eilohedra levicula*
Epistominella	nova	Pseudoparrella garrisoni
Pulvinulinella	pacifica	Epistominella pacifica
Pulvinulinella	parva	Epistominella pacifica
Pulvinulinella	cf. P. pontoni	Pseudoparrella californica
Epistominella	pontoni var. californica	Pseudoparrella californica
Pulvinulinella	purisima	Megastomella purisima
Pulvinulinella	relizensis	Pseudoparrella relizensis
Epistominella	sandiegoensis	Pseudoparrella exigua
Pulvinulinella	smithi	Epistominella smithi
Pulvinulinella	subperuviana	Pseudoparrella subperuviana
Pulvinulinella	subperuviana var. minuta	Pseudoparrella minuta
Pulvinulinella	tenuicarinata	Osangularia tenuicarinata*

in *Epistominella* or *Eponides,* and Uchio suggested (1960, p. 67) that it was an *Alabamina.* However, the species has a radial crystalline wall structure and bilamellid septa, thus excluding it from *Epistominella* or *Alabamina* and allying it with the Eponididae Hofker. The apertural characters and gross test morphology differ from previously described genera of Eponididae, hence a new genus is erected.

Family EPONIDIDAE Hofker, 1951
Genus EILOHEDRA Lipps, gen. nov.

Type species: *Epistominella levicula* Resig, 1958, Micropaleontology, vol. 4, no. 3, p. 304, text-fig. 16a-c.

Description: Test free, small, trochospiral with numerous whorls, tightly coiled, spiral side convex, umbilical side flattened and depressed in umbilical area, outline circular, periphery broadly rounded. Chambers wide, rhomboid in spiral view, trigonal in umbilical view. Sutures radial, recurved on umbilical side. Wall calcareous, hyaline, perforate, crystalline structure radial, septa bilamellid. Aperture extending along basal suture of last chamber between umbilicus and periphery, extending vertically up face of last chamber near periphery, bordered by lip, depressed in apertural face of chamber.

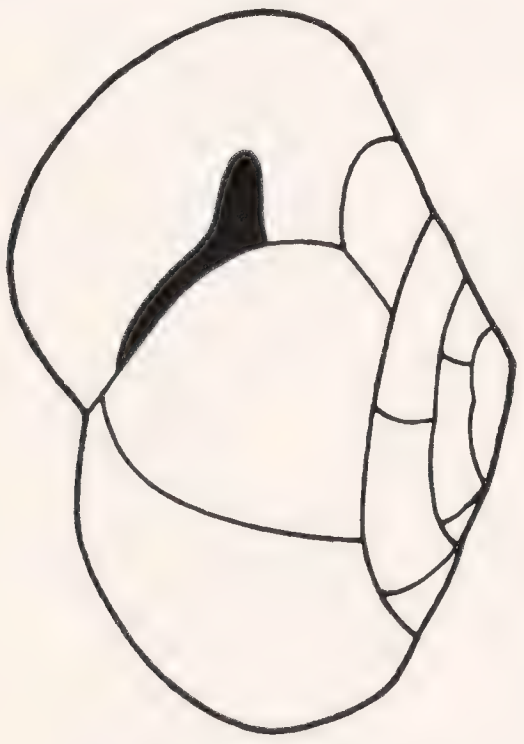

Figure 3. *Eilohedra levicula* (Resig) showing distinctive aperture depressed in face of last chamber.

Discussion: This new genus is distinguished from all other genera with radially constructed test walls and bilamellid septa by the small, tightly coiled test with broadly rounded periphery and distinctive aperture (Figure 3). It is placed in the Eponididae because of the trochospiral test and apertural position.

Eilohedra is very similar to *Svratkina* Pokorny, whose wall structure is unknown, but differs primarily in lacking a tuberculated surface.

The generic name is from the Greek *eilo* meaning "roll up, twist"; +*hedra* meaning "abode, dwelling", in reference to the tightly coiled test. Gender: Feminine.

Pulvinulinella tenuicarinata: Cushman and Siegfus (1935, p. 95) originally described this species from the Eocene Kreyenhagen Shale in Fresno County, California. It was transferred to *Parrella* [=*Osangularia*] by Mallory (1959, p. 240).

V. DESCRIPTIONS OF TYPE AND CALIFORNIA SPECIES

The type species of the genera described in sections III and IV and the valid species recognized as Pseudoparrellidae in California are described in alphabetical order by genus and species. In order to record their distribution, the synonymies include all known references to occurrences of these species, except for some widely distributed species reported from many places throughout the world. Except where specimens were adequately illustrated or reexamination was possible, no attempt was made to determine the validity of the reports, and each author's identification is assumed to be accurate. The age of each California Miocene record is given in local stage names. Previous interregional correlation of these stages has recently been questioned (Lipps, 1964, p. 114). Therefore, the assignments given by Kleinpell (1938) are used tentatively in this report. These are as follows: Zemorrian=lower lower Miocene; Saucesian=upper lower Miocene; Relizian=lower middle Miocene; Luisian=upper middle Miocene; Mohnian=lower upper Miocene; Delmontian=upper upper Miocene.

Family PSEUDOPARRELLIDAE Voloshinova
Genus AMBITROPUS Lipps
AMBITROPUS EVAX (Bandy)
Pl. I, figs. 11a-c

Epistominella evax BANDY, 1953, Jour. Paleontology, vol. 27, no. 2, p. 179, pl. 23, figs. 1a-c (Recent, off San Francisco, at 1800 ft.).

Epistominella thalmanni (Stainforth and Stevenson). SMITH, P. B., 1960, U. S. Geol. Survey, Prof. Paper 294-M, p. 487, pl. 5, figs. 9-11 (Mohnian, San Juan Capistrano area). (NOT *Palmerinella thalmanni* Stainforth and Stevenson, 1948.)

Epistominella cf. *E. evax* Bandy. SMITH, P. B., *in* Winterer and Durham, 1962, U. S. Geol. Survey, Prof. Paper 334-H,

p. 288 [table] (u. Miocene, S. E. Ventura basin).

Description: Test free, medium in size, trochospiral, flattened, of about 2½ whorls, outline oval, lobate, periphery carinate, keel of varying width, sharply rounded. Spiral side flat, all whorls, chambers, and proloculus visible, initial whorl raised, second whorl depressed, final part elevated above preceding whorls. Umbilical side low, slightly convex in varying degrees, last whorl and 6 to 7 chambers visible. Chambers about 17 in number, inflated, crescent-shaped on both sides, increasing rapidly in size in last whorl, curved back over preceding chambers, overlapping preceding whorls completely on umbilical side and slightly on spiral side, proloculus globular. Sutures distinct, limbate, strongly curved backward on both sides of test. Wall calcareous, finely perforate, surface smooth, crystal structure radial, septa monolamellid. Aperture basal, equatorial, a wide vertical slit in final chamber face, top pointed, both sides bordered by a rim formed by the peripheral keel bifurcating around aperture.

Discussion: This species is the type for *Ambitropus,* to which one other species, *Palmerinella thalmanni* Stainforth and Stevenson, 1948=*A. thalmanni* (Stainforth and Stevenson), can be assigned. Smith (1960, p. 487) stated that specimens from the San Juan Capistrano area in Southern California were identical to the types of *A. thalmanni* from the lower Miocene of Ecuador. Comparisons of Smith's specimen (USNM 624843) with a large number of *A. evax* from rocks of the same age at Newport Bay, California, and with the type specimens of *A. evax* and *A. thalmanni,* indicate that the California specimens are distinct from those of Ecuador. Variants identical to Smith's specimens and the type specimens of *A. evax* are present in the Newport Bay assemblage, yet none of the specimens closely resembled the types of *A. thalmanni. Ambitropus evax* is differentiated from *A. thalmanni* by its more curved sutures, more rapidly increasing chamber size resulting in an oval rather than circular test outline, and by the larger size.

Type locality and occurrence: This species was originally described from the south side of Cordell Bank off San Francisco. The only fossil record is from the upper Miocene of California. The species apparently lives in depths greater than 567 m, at low temperature (5.2°C to 5.5°C) and oxygen content (0.4‰), and at normal salinity (Bandy, 1953).

Genus CONCAVELLA Lipps

CONCAVELLA GYROIDINAFORMIS (Cushman and Goudkoff)

Pl. II, figs. 1a-3b

Pulvinulinella gyroidinaformis CUSHMAN and GOUDKOFF, 1938, Cushman Lab. Foram. Res., Contr., vol. 14, pt. 1, p. 2 (l. Mohnian, east and west sides San Joaquin Valley; Mohn Spring, Santa Monica Mts.; San Jose Hills west of Pomona; Palos Verdes Hills). KLEINPELL, 1938, Miocene stratigraphy of California, Tulsa, p. 328, pl. 18, figs. 17, 18, 19 (u. Luisian, u. and l. Mohnian, eastern Santa Monica Mts., Round Mountain area, eastern Kern Co.; San Pablo Creek, Contra Costa Co.). FERGUSON, 1943, Calif. Div. Mines, Bull. 118, p. 246, fig. 98, 5a-c (Tertiary, east side San Joaquin Valley). GOUDKOFF, 1943, Calif. Div. Mines, Bull. 118, p. 251, figs. 99a-b [charts] (l. Mohnian, west side San Joaquin Valley). KLEINPELL *in* Woodring, Bramlette and Kew, 1946, U. S. Geol. Survey, Prof. Paper 207, p. 33 [list] (Palos Verdes Hills). SAN JOAQUIN GEOL. SOC., 1959, Guidebook Chico Martinez Creek area field-trip, p. 4, 13 (l. Mohnian, Chico Martinez Creek, San Joaquin Valley). HUGHES, 1963, Amer. Assoc. Petrol. Geol. and Soc. Econ. Paleont. and Mineral., Pacific Sect., Guidebook Geology Salinas Valley and San Andreas Fault, 1963, p. 94, 95 (l. Mohnian, Salinas Valley).

Pulvinulinella gyroidinaformis Kleinpell MS. CANFIELD, 1939, Amer. Assoc. Petrol. Geol., Bull., vol. 23, no. 1, p. 64, 65 (m. Miocene, Santa Maria Valley).

Pseudoparrella gyroidinaformis (Cushman and Kleinpell). CROUCH, 1952, Amer. Assoc. Petrol. Geol., Bull., vol. 36, no. 5, p. 816 (Miocene, West Cortez Basin, off California).

Epistominella gyroidinaformis (Cushman and Goudkoff). NATLAND and ROTHWELL, 1954, Calif. Div. Mines, Bull. 170, chap. 3, p. 34, fig. 2, no. 13 (l. Mohnian, Topanga Canyon). NATLAND, 1957, Geol. Soc. America, Mem. 67, vol. 2, pl. 6 (following p. 572) [list] (Mohnian, southern San Joaquin Valley). SMITH, P. B., 1960, U. S. Geol. Survey, Prof. Paper 294-M, p. 487 (u. Luisian, l. Mohnian, Santa Ana Mts.; San Juan Capistrano area). COOPER, 1961, Cushman Found. Foram. Res., Contr., vol. 12, pt. 2, table 2 (reworked into Recent beach sands, Half Moon Bay). BANDY and KOLPACK, 1963, Micropaleontology, vol. 9, no. 2, p. 163, tables (l. Mohnian, Santa Ynez Mts.). MARTIN, 1963, Amer. Assoc. Petrol. Geol., Bull., vol. 47, no. 3, p. 443 (late Miocene, west of Bakersfield).

Epistominella ("Pulvinulinella") gyroidinaformis (Cushman and Goudkoff). NATLAND and ROTHWELL, 1954, Calif. Div. Mines, Bull. 170, chap. 3, p. 35.

Epistominella "Pulvinulinella" gyroidinaformis (Cushman and Goudkoff). MARTIN, 1963, Amer. Assoc. Petrol. Geol., Bull., vol. 47, no. 3, p. 441, 444. MARTIN, 1963, Amer. Assoc. Petrol. Geol., Bull., vol. 47, no. 9, p. 1773 (late Miocene, west of Bakersfield).

Description: Test free, small to medium in size, trochospiral, concavo-convex, about 2 whorls, outline generally round or may tend to be oval, in some specimens last few chambers tend to uncoil, or coil onto umbilical side of test, periphery broadly rounded, spiral edge of periphery keeled, keel of variable width, round, raised. Spiral side concave in varying degrees, all whorls, chambers and proloculus visible, chambers on spiral side crescent-shaped, flattened, strongly overlapping previous chambers. Umbilical side generally strongly convex, final and part of penultimate whorls visible, umbilicus open, chambers on umbilical side strongly inflated, trigonal to square, slightly overlapping previous chambers. Sutures distinct, radial and depressed on umbilical side, limbate and strongly curved back on spiral side. Wall hyaline, calcareous, finely perforate, crystalline structure radial, septa monolamellid. Aperture a narrow slit, depressed in face of last chamber, bordered by a very slight raised and inturned rim, parallel to periphery of test on umbilical side, basal in position with lower ¼ to ⅓ of slit slanted toward umbilical side, upper part slanted toward spiral side, more rarely aperture may tend to become areal.

Discussion: Concavella gyroidinaformis is differentiated from all other species of Pseudoparrellidae by its concave spiral side, by a tendency for the last chambers to uncoil, and by an areal aperture in some specimens. Assemblages with specimens that have uncoiling final chambers and an areal aperture (Pl. II, figs. 2a-c) occur somewhat higher in the lower Mohnian than assemblages consisting of only typically enrolled forms (Pl. II, figs. 1a-c, 3a-c). However, typical specimens occur in the same samples and intergrade with those having areal apertures. Therefore the two forms are considered conspecific.

Type locality and occurrence: This species was originally described from the Shale Hills (Sec. 10, T. 27 S., R. 18 W.) in Kings County, California. It is known in California from Contra Costa County (38°N. Lat.) south to Orange County (33.5°N.), occurring in very fine-grained sediments with other foraminifera indicative of water deeper than 1500 m. (see Brandy and Kolpack, 1963, text-fig. 35).

Concavella gyroidinaformis is considered indicative of the lower part of the Mohnian Stage, although it has also been reported from the upper Luisian (Kleinpell, 1938; Smith, 1960) and the upper Mohnian (Kleinpell, 1938).

Genus EPISTOMINELLA Husezima and Maruhasi

EPISTOMINELLA PACIFICA (Cushman)

Pl. II, figs. 5a-c, 7a-c

Pulvinulinella pacifica CUSHMAN, 1927, Calif. Univ., Scripps Inst. Oceanogr., Bull., Tech. Ser., vol. 1, no. 10, p. 165, pl. 5, figs. 14, 15 (Recent, off Oregon, central and southern California, Gulf of Panama). CUSHMAN, STEWART, and STEWART, 1930, San Diego Soc. Nat. Hist. Trans., vol. 6, no. 2, p. 73, pl. 6, figs. 5a-c (Miocene and Pliocene, Humbolt Co.). STEWART and STEWART, 1930, Amer. Assoc. Petrol. Geol., Bull., vol. 14, no. 11, p. 1448 (u. Delmontian, Puente Hills). ADAMS, 1932, Micropaleontology Bull., Stanford, vol. 3, no. 4, pl. 1, figs. 5a-c; pl. 3, figs. 2a-c (Pliocene, Orange Co.). NATLAND, 1933, Calif. Univ., Scripps Inst. Oceanogr., Bull., Tech. Ser., vol. 3, no. 10, p. 228 (Recent, off Los Angeles; Pliocene, Hall Canyon, Ventura Co.). STEWART and STEWART, 1933, San Diego Soc. Nat. Hist., Trans., vol. 7, no. 21, p. 267 (upper Pliocene, Seven Mile Beach, San Mateo Co.). WOODRING, BRAMLETTE and KLEINPELL, 1936, Amer. Assoc. Petrol. Geol., Bull., vol. 20, no. 2, p. 141 (u. Mohnian, Palos Verdes Hills). KLEINPELL, 1938, Miocene stratigraphy of California, Tulsa, p. 328 (l. Relizian—Pliocene, California). KLEINPELL *in* Woodring, Bramlette and Kew, 1946, U. S. Geol. Survey, Prof. Paper 207, p. 33 (Miocene, Palos Verdes Hills).

Pulvinulinella pacific NATLAND, 1933, Calif. Univ., Scripps Inst. Oceanogr., Bull., Tech. Ser., v. 3, no. 13, chart.

Pseudoparrella pacifica (Cushman). CUSHMAN, 1948, Foraminifera their classification and economic use, Harvard, p. 544, pl. 33, figs. 2a-b (refigured). CROUCH, 1952, Amer. Assoc. Petrol. Geol., Bull., vol. 32, no. 5, p. 836, pl. 6, fig. 1 (Recent, off Southern California, Mexico; Pliocene, Los Angeles basin). MARTIN, 1952, Cushman Found. Foram. Res., Contr., vol. 3, pt. 3-4, p. 116, table 3. SHCHEDRINA, 1953, Trudy Zool. Inst., Akad. Nauk SSSR, vol. 13, p. 16, 30 (Recent, SE part of Okhotsk Sea). CROUCH, 1954, Jour. Sed. Petrol., vol. 24, no. 3, p. 189, table (Miocene to Recent, Southern California). SUBBOTINA *in* Rauzer-Chernousova and Fursenko, 1959, Osnovy Paleontologii, Obshchaya Chasti, Prosteyshie, Akad. Nauk SSSR, p. 272, text-figs. 497a-c (m. Miocene, Sakhalin). SAIDOVA, 1961, Trudy Inst. Okeano., Akad. Nauk SSSR, vol. 45, p. 65 (Recent, NE Pacific Ocean).

SAIDOVA, 1961, Ekologiya foraminifer i paleogeografiya dal'nevostochnykh morey SSSR, i severo-zapadnoy chasti Tikhogo Okeana, Inst. Okeano., Akad. Nauk SSSR, p. 65, pl. 20, fig. 135 (Recent, Bering Sea, NW Pacific Ocean, Okhotsk Sea; pre-Recent, Sea of Japan). SAIDOVA, 1962, Voprosy Mikropaleontologii, vyp. 6, p. 37, 58, 62 (Recent, E. side of Kamchatka Peninsula). MALLORY, *in* Moore, 1963, U. S. Geol. Survey, Prof. Paper 419, p. 86, 87 (lower Miocene, Astoria, Oregon). SAIDOVA, 1964, Trudy Inst. Okeano., Akad. Nauk SSSR, vol. 48, p. 102 (Recent, NE Pacific Ocean).

Epistominella pacifica (Cushman). MARTIN, 1952, Cushman Found. Foram. Res., Contr., vol. 3, pt. 3-4, p. 136, pl. 24, figs. 8a-c (upper and lower Pliocene, Los Angeles basin). BANDY, 1953, Jour. Paleontology, vol. 27, no. 2, p. 177, pl. 23, figs. 2a-c (Recent, off San Francisco and Poirt Arguello). BANDY, 1953, Jour. Paleontology, vol. 27, no. 2, p. 201, 202 (upper Miocene, Wheeler Canyon; Pliocene, Ventura Co.). NATLAND and ROTHWELL, 1954, Calif. Div. Mines Bull. 170, chap. 3, p. 34, fig. 2, no. 7 (Pliocene and upper Miocene, Los Angeles and Ventura basins). BANDY, 1955, Cushman Found. Foram. Res., Contr., vol. 6, pt. 2, p. 77 (Pliocene, Purisima Fm., Santa Cruz). HARRINGTON, 1955, Cushman Found. Foram. Res., Contr., vol. 6, pt. 4, p. 125, 126 (Pliocene, Purisima Fm., Half Moon Bay). ZALESNY, 1959, Micropaleontology, vol. 5, no. 1, p. 124 (Recent, Santa Monica Bay). BANDY, 1960, Jour. Paleontology, vol. 34, no. 4, p. 678, text-figs. 6, 7 [charts] (Pliocene, Ventura basin). BANDY and ARNAL, 1960, Amer. Assoc. Petrol. Geol., Bull., vol. 44, no. 12, p. 1927 (Miocene). SMITH, P. B., 1960, U. S. Geol. Survey, Prof. Paper 294-M, p. 487, pl. 58, figs. 12-14 (Mohnian, Santa Ana Mts., San Juan Capistrano area). SMITH, *in* Winterer and Durham, 1962, U. S. Geol. Survey, Prof. Paper 334-H, p. 295 [table], p. 313 [list], pls. 48, 49 [tables] (upper Miocene to Pliocene, SE Ventura basin). VELLA, 1962, Tuatara, vol. 10, no. 1, p. 31 [chart]. COCKBAIN, 1963, Cushman Found. Foram. Res., Contr., vol. 14, pt. 2, table 2 (Recent, Juan de Fuca Strait, Strait of Georgia, British Columbia). NATLAND, 1963, Jour. Paleontology, vol. 37, no. 4, p. 949, figs. 2, 3 [charts] (upper Pliocene, Hall Canyon, Ventura Co.). SMITH, P. B., 1963, U. S. Geol. Survey, Prof. Paper 475-C, art. 79, p. C75, C76 [tables] (Recent; Pleistocene, Gulf of Alaska). BANDY and RODOLFO, 1964, Deep-Sea Res., vol. 11, no. 5, table 4 (fossil?, Peru-Chile Trench).

Pseudoparella pacifica (Cushman). VOLOSHINOVA *in* Voloshinova and Dain, 1952, Trudy VNIGRI, nov. ser., vyp. 63, p. 83, pl. 1, figs. 4a-c (middle to upper Miocene, Sakhalin; middle to upper Miocene, Pliocene, California; Recent, Pacific Ocean). SAIDOVA, 1960, Mezhdun. Geol. Kongr., 21 sess., 1960, Dokl. Sov. Geol., p. 62, 63 (Recent, North Pacific Ocean). SAIDOVA, 1960, Trudy Inst. Okeanol., Akad. Nauk SSSR, vol. 32, p. 128, 136, 137, 140, 141, 145 (Recent, Sea of Okhotsk, off SW Kamchatka Peninsula). SAIDOVA, 1961, Trudy Inst. Geol., Akad. Nauk Estonskoi SSR, vol. 8, p. 200 (Recent, North Pacific Ocean).

Pulvinulinella (Epistominella) pacifica (Cushman). NATLAND, 1952, Pacific Petrol. Geol., vol. 7, no. 2, p. 2 [chart] (Wheelerian = Pliocene).

"Pulvinulinella" pacifica (Cushman). MALLORY *in* Moore, 1963, U. S. Geol. Survey, Prof. Paper 419, p. 86.

Pulvinulinella parva CUSHMAN and LAIMING, 1931, Jour. Paleontology, vol. 5, no. 2, p. 115-116, pl. 13, figs. 5a-c (lower Miocene, Los Sauces Creek, Ventura Co.). KLEINPELL, 1938, Miocene stratigraphy of California, Tulsa, p. 329 (lower Miocene, Chico Martinez Creek, Kern Co.; Astoria, Oregon, Rich's Passage, Washington). CUSHMAN, STEWART and STEWART, 1947 [1948], Oregon Dept. Geol. and Mineral Indust., Bull. 36, pt. 2, p. 48, pl. 6, figs. 5a-c (Miocene, Agate Beach, Oregon). RAU, 1948, Jour. Paleontology, vol. 22, no. 6, p. 780, pl. 119, figs. 12-14 (lower to middle Miocene, Grays Harbor, Washington). STEWART, 1956, The Ore.-bin, vol. 18, no. 1, p. 4.

Pseudoparrella parva (Cushman and Laiming). RAU, 1951, Jour. Paleontology, vol. 25, no. 4, p. 449, pl. 67, figs. 1, 2 (lower Miocene, Willapa Valley, Washington). STEWART, 1956, The Ore.-bin, vol. 18, no. 1, p. 5, 6 (lower Miocene, Depoe Bay south to Newport, Oregon; Agate Beach, Oregon). STEWART, 1956, The Ore.-bin, vol. 18, no. 7, p. 58. MALLORY *in* Moore, 1963, U. S. Geol. Survey, Prof. Paper 419, p. 87 (lower Miocene, Yaquina Head area, Oregon).

Epistominella parva (Cushman and Laiming). RAU, 1958, U. S. Geol. Survey, Oil and Gas Chart, O. C. 57, chart 2 (lower Miocene, Willapa Valley, Washington). KLEINPELL and WEAVER, 1963, Univ. Calif. Pubs. Geol. Sci., vol. 43, no. 1, fig. 4, chart (Zemorrian and Saucesian, Los Sauces Creek, Ventura Co.). RAU, 1964, U. S. Geol. Survey, Prof. Paper 374-G, p. G5. MALLORY *in* Moore, 1963, U. S. Geol. Survey, Prof. Paper 419, p. 86. SNAVELY, RAU and WAGNER, 1964, The Ore.-bin, vol. 26, no. 8, p. 146 [list], (lower Miocene, Yaquina Bay area, Oregon).

Epistominella pacifica parva (Cushman and Laiming). BANDY and KOLPACK, 1963, Micropaleontology, vol. 9, no. 2, p. 163 (lower Miocene, Tecolote Tunnel, Santa Ynez Mts., Santa Barbara Co.).

Description: Test free, small to medium in size, trochospiral, 2½ to 3½ whorls,

outline circular to slightly ovate, margin even to slightly lobate, periphery carinate, keel narrow, rounded, raised, finely perforate. Spiral side flat to slightly convex, initial stages raised in differing degrees, last whorl flattened to slightly convex, all whorls, chambers and proloculus visible. Umbilical side very strongly convex, 5 to 8 chambers and last whorl visible, umbilicus open or closed, deep and bordered by a keeled edge when open. Chambers 23 to 26 in number, increasing gradually in size with growth, rhomboid on spiral side, 2 to 3 times as wide as high, narrower at base, early chambers square, curved back over preceding chamber, on umbilical side wedge-shaped, curved backward, narrow at base, broad at top, commonly slightly inflated, extension toward umbilicus commonly covering it, overlapping fore-edge of previous chambers, completely overlapping previous whorl. Sutures distinct, limbate, raised and tending to be tangential on spiral side, slightly depressed and curved backward on umbilical side. Wall calcareous, finely perforate, surface smooth, crystalline structure radial, septa monolamellid. Aperture a narrow vertical slit, basal, extending to near top of final chamber face, arched toward umbilical side with bend about ¼ of length of aperture, top pointed, wider at base, opening bordered by a narrow rim, apertural face flat, bordered by peripheral keel on spiral edge, very acute or commonly keeled top edge extending from periphery to umbilicus, top edge straight, curved sharply down to umbilicus, lower margin straight, indented to join aperture.

Discussion: Epistominella pacifica is distinguished by its nearly circular outline, strongly umbilico-convex test, and nearly flattened or slightly convex spiral side.

Epistominella parva is placed in synonymy with *E. pacifica* as it differs only in size. The holotype of *E. parva* is identical to smaller specimens of *E. pacifica.* Assemblages of both forms intergrade and are indistinguishable. Lewis Martin (1952, p. 136) noted that *E. smithi* may be conspecific with *E. pacifica;* however, *E. smithi* differs in its more rapidly increasing chamber size with growth, resulting in an oval outline, and in the less convex test.

Epistominella carinata Voloshinova, 1960, *E. troptunensis* Voloshinova, 1960, from the Miocene of Sakhalin and *E. pulchella* Husezima and Maruhasi, 1944, from the Pliocene of Japan are similar to *E. pacifica* and may prove synonymous.

Type locality and occurrence: Cushman (1927, p. 165) originally described *Epistominella pacifica* from Recent sediments off central California (Lat. 36°50′ N; Long. 122°15′ W; 735 fathoms). It has since been reported from lower Miocene to Recent deposits on both sides of the North Pacific Ocean. On the east side, the species has been reported from Panama to the Gulf of Alaska, but as a fossil only from Southern California northward. On the west side, it lives in the Bering Sea south to the Okhotsk Sea. The species has also been found in sediment cores throughout the same area and in the Sea of Japan (Saidova, 1961). It was reported in the Miocene deposits of Sakhalin (Voloshinova, 1952). The smaller form given the name *E. parva,* originally described from Los Sauces Creek, Ventura County, California (Cushman and Laiming, 1931), has been recorded from elsewhere in California, and from Oregon and Washington. This name has been given to specimens occurring in the lower Miocene.

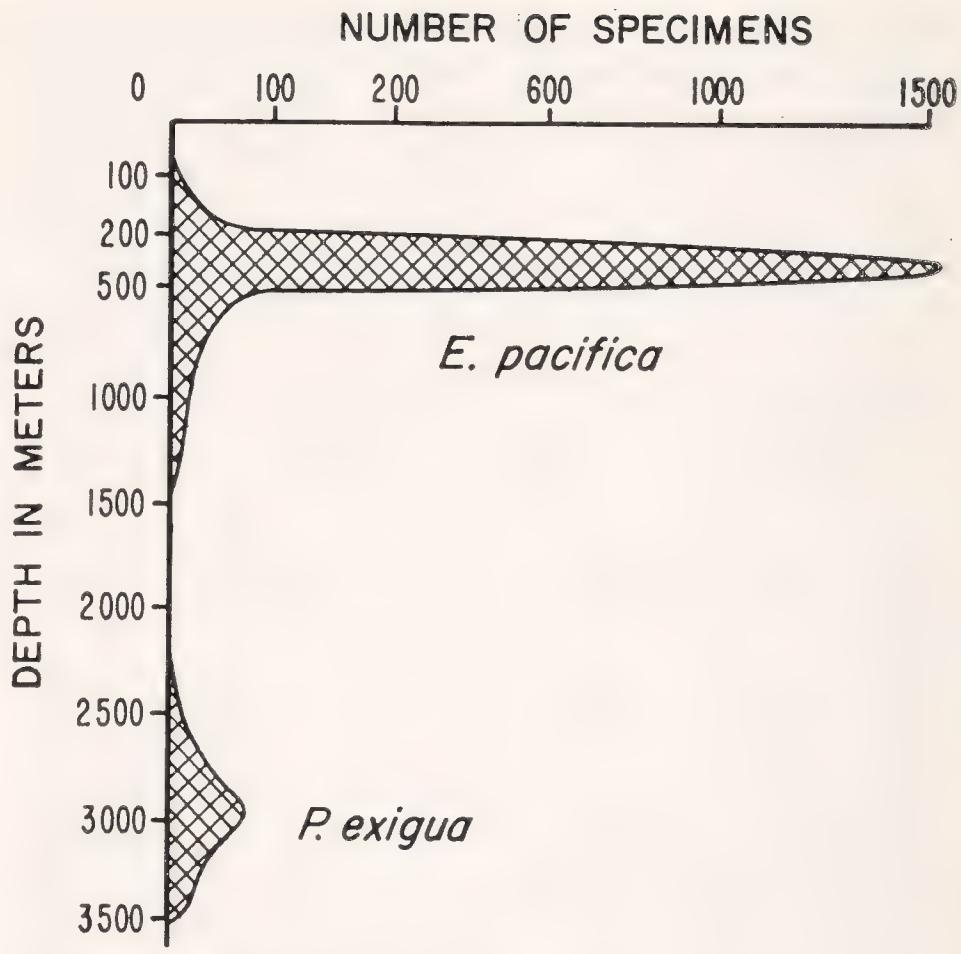

Figure 4. Quantitative distribution of *Epistominella pacifica* (Cushman) and *Pseudoparrella exigua* (Brady) with depth in the Bering Sea and Western North Pacific Ocean. (From Saidova, 1961, text-fig. 19)

Epistominella pacifica has been found in Recent sediments from 34 m to 2300 m in depth (see Table 3) although it occurs most abundantly between 150 m and 600 m (Figure 4; Saidova, 1961; Natland, 1933). The occurrence of *E. pacifica* in abundance is discontinuous in the western Pacific Ocean (Saidova, 1962, p. 37) and probably also in the eastern Pacific. Apparently factors other than depth are important in the distribution of this species, but detailed information has not been recorded. The spe-

cies has been found on silt- to fine sand-sized sediment in waters of about normal salinity and commonly 2° to 7°C.

EPISTOMINELLA PULCHELLA Husezima and Maruhasi

Pl. II, figs. 4a-c

Epistominella pulchella HUSEZIMA and MARUHASI, 1944, Jour. Sigenkagaku Kenkyusyo, vol. 1, no. 3, p. 398, pl. 34, figs. 10a-b.

Epistominella puchella IWASA, 1955, Jour. Geol. Soc. Japan, vol. 61, no. 712, p. 6.

Description: Test free, small, trochospiral, inequally biconvex, consisting of three whorls, outline circular, very slightly lobate, periphery carinate, with narrow, slightly raised, rounded keel. Spiral side low, convex, all chambers, whorls, and proloculus visible, initial portion of spire is highest part, below center of test. Umbilical side convex, last whorl of six chambers, edge of aperture toward spiral side visible, umbilicus closed. Chambers 16 in number, opaque, curved back over top of preceding chambers, on spiral side rectangular, width greater than height, on umbilical side narrow at base widening at top, overlapping preceding chamber, inflated with wide extension toward umbilicus, proloculus rounded. Sutures distinct, narrow, of differing width, translucent, flush with surface of test and curved back slightly on spiral side, depressed and at first radial on umbilical side, then curved backwards in middle of chamber height. Wall calcareous, smooth, thickest in center of test, finely perforate. Aperture a narrow slit, in a depression on umbilical side of test, extending from base to top of chamber, basal one-fourth at angle away from spiral side, curved sharply back toward spiral side thence straight to top, top rounded, edge toward spiral side partly beneath peripheral keel, apertural face bordered by peripheral keel on spiral side with lower margin indented to join aperture, otherwise straight, and edges smoothly rounded.

Discussion: This species is similar to *E. pacifica* but differs in the lenticular test. However, examination of a large series of the Japanese species may show it to be synonymous. As previously noted, specimens of several other species from eastern Russian and Japan also should be compared with *E. pulchella.*

Type locality and occurrence: Epistominella pulchella was described from the Pliocene lower Haizume Formation at 214 m in a core in the Kasiwazaki Oil Field, Niigata-Ken, Japan. The species was reported also from the Miocene (Fujita and Ito, 1957, p. 502) and the Recent (Takayanagi, 1953, p. 84) in 40 m on a silt and clay bottom.

EPISTOMINELLA SMITHI (R. E. and K. C. Stewart)

Pl. II, figs. 6a-c

Pulvinulinella smithi R. E. and K. C. STEWART, 1930, Jour. Paleontology, vol. 4, no. 1, p. 70, pl. 9, figs. 4a-c (Pliocene, Ventura, Calif.). CUSHMAN and MOYER, 1930, Cushman Lab. Foram. Res., Contr., vol. 6, pt. 3, p. 60 (Recent, off San Pedro, Calif.).

Pseudoparrella smithi (R. E. and K. C. Stewart). CROUCH, 1951, Cushman Found. Foram. Res., Contr., vol. 2, pt. 1, p. 10 (lower Pliocene, west side Newport Lagoon, Calif.). PHLEGER, 1951, Soc. Econ. Paleon. and Mineral., Spec. publ. no. 2, p. 68, 69 [tables] (Recent? cores, San Diego Trough). CROUCH, 1952, Amer. Assoc. Petrol. Geol., Bull., vol. 32, no. 5, p. 836, pl. 6, figs. 2-3. (Recent, basins off Southern California; Pliocene, Los Angeles basin).

Epistominella smithi (R. E. and K. C. Stewart). BANDY, 1953, Jour. Paleontology,

TABLE 3

Some reported ecologic data for Epistominella pacifica *(Cushman)*

Locality	Depth (M)	Temperature (°C)	Salinity (‰)	Reference
Off Panama	1410 to 2124	–	–	Cushman, 1927
Off Baja California, Mexico	2640	–	–	Cushman, 1927
Off So. California	252 to 1104	–	–	Cushman, 1927
Off San Pedro, California	233 to 2333	11 to 2.9	–	Natland, 1933
Santa Monica Bay, California	600 to 920	5 to 6	34.4 to 34.45	Zalesny, 1959
Off Point Arguello, California	600 to 800	4.0 to 5.5	34.2 to 34.4	Bandy, 1953
Off Central California	870 to 1632	–	–	Cushman, 1927
Off San Francisco, California	2000 to 2300	1.9 to 2.2	34.6 to 34.7	Bandy, 1953
Juan de Fuca Strait, Canada	34 to 184	6.7 to 7	32.5 to 34.0	Cockbain, 1963
Gulf of Alaska	230 to 810	–	–	Smith, 1963
Western Bering Sea	136 to 1201	–	–	Saidova, 1961, 1962
Off SE Kamchatka	126 to 1700	–	–	Saidova, 1961, 1962
West-central Okhotsk Sea	600 to 1000	2.0	33.5	Saidova, 1960, 1961, 1962

vol. 27, no. 2, p. 177, pl. 23, figs. 7a-c (Recent, off Point Arguello, Calif.). WALTON, 1955, Jour. Paleontology, vol. 29, no. 6, p. 1008, pl. 103, figs. 22, 23 (Recent, Todos Santos Bay, Baja Calif., Mexico). WHITE, 1956, Jour. Paleontology, vol. 30, no. 2, p. 257, pl. 32, figs. 1a-c (Pliocene, Capistrano Beach, Calif.). PIERCE, 1956, Jour. Paleontology, vol. 30, no. 6, p. 1300, pl. 139, figs. 14a-c (lower and upper Mohnian, Benedict Canyon, Los Angeles). BANDY and ARNAL, 1957, Amer. Assoc. Petrol. Geol., Bull., vol. 41, no. 9, p. 2041, 2042, 2051 [tables] (Recent, off Central America). RESIG, 1958, Micropaleontology, vol. 4, no. 3, p. 306 (Recent, Santa Cruz Basin, Calif.). ZALESNY, 1959, Micropaleontology, vol. 5, no. 1, p. 124 (Recent, Santa Monica Bay, Calif.). GREEN, 1960, Micropaleontology, vol. 6, no. 1, p. 74 (Recent, Arctic Ocean). BANDY, 1960, Jour. Paleontology, vol. 34, no. 4, text-fig. 7 [chart] (Pliocene-Pleistocene, Ventura basin). UCHIO, 1960, Cushman Found. Foram. Res., Spec. publ. no. 5, tables, pl. 9, figs. 8-10 (Recent, off San Diego). BANDY, 1961, Micropaleontology, vol. 7, no. 1, p. 15, pl. 5, figs. 6a-c (Recent, Gulf of California). HARMAN, 1964, Micropaleontology, vol. 10, no. 1, p. 95 (Recent, Santa Barbara basin, Calif.). SMITH, P. B., 1964, U. S. Geol. Survey, Prof. Paper 429-B, p. B44 (Recent, off El Salvador).

Epistominella pacifica smithi (R. E. and K. C. Stewart). BANDY, 1964, Jour. Paleontology, vol. 38, no. 1, p. 141 (Recent-sub-Recent, Santa Monica and San Pedro basins, Calif.). BANDY and RODOLFO, 1964, Deep-Sea Res., vol. 11, no. 5, tables 3, 4, fig. 5a (Recent, Peru-Chile Trench, 796 m).

Not *Pulvinulinella smithi* Stewart. SACAL and DEBOURLE, 1957, Mém. Soc. Geol. France, no. 78, p. 47, pl. 21, fig. 4.

Description: Test free, medium in size, trochospiral, inequally biconvex, consisting of two and one-half whorls, outline ovate, margin lobate, periphery carinate, keel of variable width, normally narrow, rounded, slightly raised. Spiral side low, convex, all whorls, chambers and proloculus visible, initial part of spire elevated, below center of test, last whorl flattened. Umbilical side strongly convex, five to six chambers visible in last whorl, umbilicus open or closed, deep when open, commonly rimmed by ridges on chambers. Chambers fifteen in number, on spiral side crescent-shaped, upper edge an arc, lower edges form two intersecting arcs, width greater than height, curved back over preceding chamber for half its width, narrow at base becoming broad at top on umbilical side, inflated, with umbilical extension overlapping forward part of preceding chamber, some specimens with short low ridges on umbilical extension, proloculus rounded. Sutures distinct, narrow, limbate, flush on spiral side, deeply incised on umbilical side, strongly curved backwards. Wall calcareous, smooth, finely perforate. Aperture a narrow slit nearly parallel to periphery but curved slightly toward spiral side, in a depression on face of last chamber, extending from base to top of chamber, upper margin rounded, bordered by narrow rim, apertural face triangular, bordered by peripheral keel on spiral side, sharply rounded on others, lower margin of last chamber indented and joins aperture.

Discussion: Epistominella smithi is characterized by curved sutures on the spiral side and the rapidly increasing chamber size in later stages, resulting in an oval outline.

Type locality and occurrence: The type locality of *E. smithi* is in the upper Pico Formation (Pliocene) in the "mud pits at the Dent Mud Plant about 1½ miles north of Ventura and ½ mile east of Ventura Avenue at the head of Franklin Lane, Ventura County, California" (Stewart and Stewart, 1930). The type area is now covered by an avocado tree grove, and no specimens of *E. smithi* were found in samples taken farther east of the head of Franklin Lane.

This species has a geologic range from lower upper Miocene to Recent. It is reported as a fossil only from Southern California, with two doubtful exceptions: Mallory (*in* Moore, 1963) listed *Parrella* cf. *P. smithi* (R. E. and K. C. Stewart) from the lower Miocene Astoria Formation in Oregon; and Iwasa and Kikuchi (1954) identified specimens from the Middle Miocene Sugota Formation in the Dewa Hills, Akita Prefecture, Japan, as *Epistominella smithi*. *Epistominella smithi* is recorded in Recent seas from Southern California southward to South America. It was also reported from the Arctic Ocean northwest of Ellesmere Island (Green, 1960) but, as it has not otherwise been recorded living north of Point Arguello, California, this report may be incorrect.

The species lives in water of 8.5° to 4.0°C and rarely at cooler temperatures (Crouch, 1952), in depths ranging from about 67 to 2734 m (see Table 4), and on finer-grained substrates.

Genus MEGASTOMELLA Faulkner, de Klasz and Rérat

MEGASTOMELLA AFRICANA Faulkner, de Klasz and Rérat

Pl. III, figs. 3a-c; text-fig. 2

Megastomella africana FAULKNER, DE KLASZ and RÉRAT, 1963, Revue de Micropaléontologie, vol. 6, no. 1, p. 20, pl. 1, figs. 1a-c.

Description: Test free, medium to large in size, trochospiral, flattened, consisting of 2 whorls, outline ovate, slightly lobate, periphery acute. Spiral side convex, apex of spire highest part, both whorls, proloculus, and all chambers except first few following proloculus are visible from exterior. Umbilical side increasing in height toward last-formed chambers, umbilicus in center, covered, the opposite margin of aperture, last whorl and nine chambers visible on umbilical side. Chambers elongate, narrow in axial region, broadened toward periphery, very slightly inflated, somewhat overlapping previous chambers, nearly completely overlapping previous whorl on spiral side and entirely on umbilical side, with inflated chamber extensions covering umbilicus. Sutures distinct, narrow, of constant thickness, depressed slightly on spiral side, more so on umbilical side, curved gently backward. Aperture a slit from base to top of chamber, parallel to periphery, pointed at top, widest at base, extending slightly toward umbilicus under umbilical extension, curved in middle toward spiral side, apertural margin sharply rounded on spiral side, broadly rounded on umbilical side.

Discussion: Megastomella africana is characterized by large size and a wide aperture which tends to lie on the umbilical side. The subspecies *M. africana compressa* Faulkner, de Klasz and Rérat, 1963, differs in having a more compressed test and a peripheral aperture (Figure 2).

Type locality and occurrence: The type locality is at 1130 m in bore hole L0 9, 8 km. WNW of Port-Gentil, Gabon, Africa. The species is known only from the lower Miocene Mandorové Formation in the western part of the Gabon basin, Africa.

MEGASTOMELLA CAPITANENSIS (Cushman and Kleinpell)

Pl. III, figs. 1a-2c

Pulvinulinella capitanensis CUSHMAN and KLEINPELL, 1934, Cushman Lab. Foram. Res., Contr., vol. 10, pt. 1, p. 18, pl. 3, figs. 3a-c (Miocene, west of Dos Pueblos Creek, Santa Barbara County, Calif.). KLEINPELL, 1938, Miocene stratigraphy of California, Tulsa, p. 327 (l. Mohnian, Santa Monica Mountains, Calif.; u. Mohnian, Palos Verdes Hills). CANFIELD, 1939, Amer. Assoc. Petrol. Geol., Bull., vol. 23, no. 1, p. 65 (m. Miocene, Santa Maria Valley oil field). CAMPBELL and CLARK, 1944, Geol. Soc. America, Spec. paper 51, p. 2. KLEINPELL *in* Woodring, Bramlette and Kew, 1946, U. S. Geol. Survey, Prof. Paper 207, p. 36 [table] (u. Mohnian, Palos Verdes Hills).

Epistominella capitanensis (Cushman and Kleinpell). DOWNS, 1955, So. Calif. Acad. Sci., Bull., vol. 54, pt. 2, p. 49 (Miocene, San Joaquin Hills, Orange Co., Calif.

Epistominella sp. PARKER, 1964, Jour. Paleontology, vol. 38, no. 4, p. 625, pl. 99, figs. 39a-c (lower Mohnian, off Guadalupe Island, Mexico).

Description: Test free, small to medium in size, flattened, trochospiral, ovate in outline, margin lobate, periphery rounded. Spiral side flattened, first formed whorls depressed, all whorls, proloculus and chambers and opposite edge of aperture visible

TABLE 4

Some reported ecologic data for Epistominella smithi *(R. E. and K. C. Stewart).*

Locality	Depth (M)	Temperature (°C)	Salinity (°/₀₀)	Reference
Off Point Arguello, California	600 to 800 m	4.0 to 5.5	34.2 to 34.4	Bandy, 1953
Basins off So. California	100 to 666-2/3	4.0 to 8.5	34.2 to 34.66	Crouch, 1952
Santa Barbara Basin, California	372 to 563	–	–	Harman, 1964
Santa Cruz Basin, California	700 to 2000	4.1 to 5.0	–	Resig, 1958
Santa Monica Bay, California	226 to 920	5 to 7	34.45 to 34.55	Zalesny, 1959
Off San Pedro, California	133-1/3	–	–	Cushman & Moyer, 1930
Off San Diego, California	314 to 1230	–	–	Uchio, 1960
Todos Santos Bay, Baja California	66-2/3 to 133-1/3	–	–	Walton, 1955
Gulf of California	610 to 2743	4.5 to 6.0	–	Bandy, 1961
Off Central America	68 to 1750	3.5 to 7.5	34.7	Bandy & Arnal, 1957
Off El Salvador	450 to 1700	3 to 5	34.56 to 34.61	Smith, 1964

from spiral side. Umbilical side convex, umbilicus covered. Chambers twelve to thirteen in number, eight in last whorl, three to four times as high as wide, increasing in height with growth, somewhat inflated, curved over previous chambers, with downward extensions on both sides of base overlapping preceding whorl, narrow at base and expanded at top. Sutures thin, radial at first, curved backward in middle of chamber height. Wall calcareous, smooth, finely perforate, opaque to nearly translucent, crystalline structure radial, septa monolamellid. Aperture a long, equatorial slit, extending from base to top of chamber face, about four or five times as long as wide, curved slightly in middle, bent toward spiral side at base, top curved, apertural margins very slightly raised, rounded, smoothly joining sides of chamber.

Discussion: This species is small and has a narrow aperture. The holotype (Pl. 3, figs. 1a-c) is unlike most specimens of this species, which do not attain such a large size. The species can be differentiated from *M. purisima* by the straighter sutures and more oval outline.

Type locality and occurrence: Megastomella capitanensis was originally described from lower Mohnian (upper Miocene) strata "232 feet stratigraphically above the top of 10 foot thick, prominent chert bed exposed at base of ocean bluffs immediately east of Dos Pueblos Creek, west of Naples" (Cushman and Kleinpell, 1934, p. 18). It was reported from Santa Maria Valley southward to near Guadalupe Island, Mexico. Parker's (1964) figured specimen from the latter locality is identical to small topotypes of *M. capitanensis.*

MEGASTOMELLA PURISIMA (Bramlette)
Pl. III, figs. 4a-c

Pulvinulinella purisima BRAMLETTE, 1950 [1951], U. S. Geol. Survey, Prof. Paper 222, p. 60, pl. 23, figs. 10-15 (Delmontian?, Topanga Canyon, Los Angeles Co.; Santa Maria District; Puente Hills).

Pseudoparrella purisima (Bramlette). ELLIS and MESSINA, 1951, Catalog of Foraminifera, suppl. 1951, no. 3.

Description: Test free, medium in size, flattened, trochospiral, ovate in outline, margin slightly lobate, periphery sharply rounded. Spiral side slightly convex, depressed in area of early whorl, parts of all whorls, 20 to 21 chambers, and proloculus visible. Umbilical side convex, umbilicus covered by chamber extensions, part of apertural margin and last whorl with nine chambers visible. Chambers 20 to 21 in number, three times as high as wide, becoming relatively higher in later chambers, slightly inflated, curved backwards over previous chambers, with a sharper bend in middle of younger chambers, overlapping edges of previous chamber and previous whorl on spiral side, completely overlapping those of previous whorl on umbilical side, umbilical extension inflated, proloculus round, raised. Sutures distinct, appearing as a thin depressed line, radial near center, curved back toward margin. Wall calcareous, smooth, finely perforate, translucent. Aperture a peripheral slit, parallel to periphery, curved, narrow, long, extending from base to rounded top of chamber face, and toward umbilicus at lower edge of umbilical extension, apertural margins rounded, smoothly joining sides of chamber.

Discussion: This species is characterized by its wide aperture, long chambers, and strongly curved sutures. Some specimens have a tendency for final chambers to coil onto the umbilical side of the test. Specimens may be concave on either side of the test as a result of the irregular coiling.

Type locality and occurrence: The type locality of *M. purisima* is "in the Monterey formation (Modelo formation of some geologists) on the east slope of the spur 0.35 mile, S. 30° E. from the intersection of Ventura Boulevard and Topanga Canyon Avenue, near Woodland Hills (formerly known as Girard) on the north slope of the Santa Monica Mountains, Los Angeles County, California" (Bramlette *in* Woodring and Bramlette, 1950). Bramlette also recorded the species from upper Miocene sediments in the Santa Maria district and Puente Hills.

Genus PSEUDOPARRELLA Cushman and ten Dam

PSEUDOPARRELLA CALIFORNICA (White)
Pl. I, figs. 6a-c

Epistominella pontoni californica WHITE, 1956, Jour. Paleontology, vol. 30, no. 2, p. 257, pl. 31, figs. 9a-c (upper Miocene, Capistrano Beach, Calif.).

Pulvinulinella cf. *P. pontoni* Cushman. KLEINPELL, 1938, Miocene stratigraphy of California, Tulsa, p. 329, pl. 16, figs. 5a-c (lower Delmontian, Reliz Canyon, Monterey Co., Calif.).

Epistominella californica White. BANDY and ARNAL, 1957, Amer. Assoc. Petrol. Geol., Bull., vol. 41, no. 9, p. 2041, 2051 (Recent, off Acapulco, Mexico).

Epistominella subperuviana californica White. BANDY and KOLPACK, Micropaleontology, vol. 9, no. 2, p. 163 (Relizian to lower Mohnian, Santa Ynez Mountains, Santa Barbara Co., Calif.).

Description: Test free, small in size, biconvex, trochospiral, consisting of 2½

whorls, outline circular to suboval, lobulate, periphery rounded. Spiral side of differing convexity, generally smoothly convex but commonly somewhat flattened, all whorls, chambers and proloculus visible. Umbilical side evenly convex, umbilical region depressed, six to nine chambers and last whorl visible, umbilicus closed. Chambers 18 to 22 in number, slightly inflated; on spiral side rhomboid in outline throughout or increasing in relative height in last whorl, lower margin lobed, extending onto previous whorl; on umbilical side wedge-shaped, narrow at base, broadening toward top of chamber, overlapping front part of previous chamber, with inflated umbilical extension; proloculus rounded. Sutures distinct, slightly limbate, depressed, radiate on umbilical side, slanted backwards on spiral side. Wall calcareous, radially-built, surface smooth, perforations numerous and obvious. Aperture a very narrow slit, slightly oblique to periphery, in a deep depression on apertural face, extending from base to top of chamber, bordered by a very narrow raised rim. Apertural face smoothly rounded from aperture joining sides of chamber, lower margin indented to join apertural margin.

Discussion: Pseudoparrella californica differs from other California species in the straighter sutures, more rounded periphery, thicker test, more inflated chambers which are square in spiral view, and in the smaller size. The species differs from the holotype of *P. pontoni* in the lower spire, more circular outline and rounded periphery.

Type locality and occurrence: The type locality is 1.8 miles south of the intersection of U.S. Hwy. 101 S, Alt., and U.S. 101 N on former U.S. 101, ⅔ the distance up cliff, in a small gully containing a drainage pipe just below a 10 inch chert bed, Capistrano Beach, California (USC loc. 150=UCLA loc. 4719).

Pseudoparrella californica has been reported from Relizian (lower middle Miocene) to Recent deposits from Santa Barbara County southward to off Acapulco, Mexico, where it was collected in 1750 m of water at 2.6 to 3.8°C and a salinity of 34.7‰.

PSEUDOPARRELLA EXIGUA (Brady)
Pl. I, figs. 9a-c

Pulvinulina exigua BRADY, 1884, Rept. Voy. Challenger, Zool., vol. 9, p. 696, pl. 103, figs. 13a-14c (Challenger Stations 332 and 160, South Atlantic Ocean and Southern Ocean).

Pulvinulinella exigua (Brady). HANNA and CHURCH, 1927, Jour. Paleontology, vol. 1, no. 3, p. 200 (Recent, off Farallon Islands, Calif.).

Pseudoparrella exigua (Brady). PHLEGER, 1951, Soc. Econ. Paleont. and Mineral., Spec. publ. no. 2, p. 69 [chart] (Recent, San Diego Trough, Calif.).

Epistominella sandiegoensis UCHIO, 1960, Cushman Found. Foram. Research, Spec. publ. no. 5, p. 68, pl. 9, figs. 6, 7 (Recent, off San Diego, Calif.; Sebastian Vizcaino Bay, Mexico).

Not *Eponides exigua* (Brady). BARBAT and JOHNSON, 1934, Jour. Paleontology, vol. 8, no. 1, p. 16, pl. 1, figs. 5-7. KLEINPELL, 1938, Miocene stratigraphy of California, Tulsa, p. 318, pl. 20, figs. 6, 10, 12.

Description: Test free, small, biconvex, trochospiral, of 3½ whorls, outline circular, margin slightly lobate, periphery acutely rounded. Umbilical side flattened, 6 chambers of last whorl visible, umbilicus covered. Spiral side convex, all chambers and proloculus visible, center of spire very nearly in center of test. Chambers 22 in number, on spiral side rhomboid in shape, about twice as wide as high, and curved back over previous chamber, on umbilical side wedge-shaped and covering previous whorl completely, proloculus round. Sutures distinct, on spiral side slightly limbate, flush and bent obliquely backwards, on umbilical side very slightly depressed and curved forward at first, then back slightly and then recurved forward. Wall calcareous, finely perforate, thin and translucent. Aperture a slit parallel to periphery on umbilical side, in slight depression on apertural face, basal, extending to top of chamber, narrower at top, bordered by narrow rim. Apertural face sharply rounded.

Discussion: This small species has been assigned to several different genera in the past although it possesses the characters of *Pseudoparrella.* It is distinguished from other species by its small size, acute periphery, and recurved sutures on the umbilical side of the test. *Epistominella sandiegoensis* Uchio is identical to the original figures of this species, hence it is considered a junior synonym.

Barbat and Johnson (1934) and Kleinpell (1938) erroneously assigned to this species specimens which have basal sutural apertures.

Occurrence: Pseudoparrella exigua originally was described from deep-water samples collected in the South Atlantic and Southern Oceans and has since been reported throughout the world. It occurs along the entire eastern side of the North Pacific Ocean, but only California records are included in the synonymy above.

The species is commonly recorded on fine-grained sediments in deep water (see Figure 4) although it is found also in shallow

water in decreased abundance. Hofker (1951) believed the species was pelagic in life because of its thin test walls, inflated chambers, widespread distribution and occurrence in *Globigerina* oozes. However, many deep-water benthonic species of foraminifera have thin walls, are widely distributed, and are found in *Globigerina* oozes. *Pseudoparrella exigua* is not found in plankton tows but is recorded as living on the bottom (see Uchio, 1960). There is no evidence to suggest a pelagic habitat.

PSEUDOPARRELLA GARRISONI Lipps, nom. nov.
Pl. I, figs. 4a-c

Epistominella nova GARRISON, 1959, Jour. Paleontology, vol. 33, no. 4, p. 669, pl. 85, figs. 11a-c (lower Miocene, Saucesian, west side of San Joaquin Valley, Calif.).

Not *Pseudoparrella nova* PISHVANOVA, 1959, Ukr. NIGRI, Minist. Geol. Okhrany nedr. SSSR, Trudy, vyp. 1, p. 12, pl. 6, figs. 2a-c.

Description: Test free, small, trochospiral, flattened, consisting of nearly 2 whorls, outline suboval, margin slightly lobate, periphery rounded. Spiral side flattened, all whorls, chambers, and proloculus visible. Umbilical side flattened, six chambers visible, slightly depressed in umbilical area, umbilicus closed. Chambers wedge-shaped on umbilical side, rhomboid to quadrate on spiral side, slightly inflated, increasing in size in last whorl, lower margin lobed, overlapping previous whorl and front part of previous chambers, with broad umbilical extensions. Sutures obscure, thin, depressed, curved backwards. Wall calcareous, smooth, perforations obscured, surface grainy in appearance. Aperture a short, narrow slit extending from base of last chamber parallel to periphery, on umbilical side of test, bordered by very narrow rim, slightly depressed. Apertural face smoothly joins chamber sides without sharp differentiation.

Discussion: This species is known from one specimen, the only one on the slide containing Garrison's type specimens which matched the description of the species. However, the original illustrations (Garrison, 1959, pl. 33, figs. 11a-c) are reversed images of this specimen. As none of Garrison's other figures are reversed, the identity of this specimen as the holotype is questionable.

The specimen has been leached or recrystallized and is not well preserved. An examination of a large sample from the type locality failed to yield additional specimens. It is placed in *Pseudoparrella* because of the rounded periphery, short rhomboid to quadrate chambers and an aperture on the umbilical side of the test. This species is separated from other species of *Pseudoparrella* by its flattened test, fewer chambers, and small size. It is similar to *Megastomella* in its flattened test.

As the specific name proposed by Garrison (July 14, 1959) is preoccupied by *Pseudoparrella nova* Pishvanova (June 24, 1959), the California species is renamed in honor of L. E. Garrison of Sacramento, California.

Type locality: Pseudoparrella garrisoni was originally described from the 2950 to 2976 foot cored interval of the Seaboard-Welsh no. 1 well, north of Coalinga, Fresno County, California. Garrison (1959, p. 664) inferred that the sediments were deposited in "depths down to approximately 200 feet."

PSEUDOPARRELLA MINUTA (Cushman and Laiming)
Pl. I, figs. 5a-c

Pulvinulinella subperuviana minuta CUSHMAN and LAIMING, 1931, Jour. Paleontology, vol. 5, no. 2, p. 116, pl. 13, figs. 6a-c (lower Miocene, Los Sauces Creek, Ventura Co., Calif.). BARBAT and VON ESTORFF, 1933, Jour. Paleontology, vol. 7, no. 2, p. 165 (lower Miocene, 7½ mi. SE of Maricopa, Calif.). KLEINPELL, 1938, Miocene stratigraphy of California, Tulsa, p. 331.

Epistominella subperuviana minuta Cushman and Laiming. KLEINPELL and WEAVER, 1963, Univ. Calif. Publs. Geol. Sci., vol. 43, no. 1, fig. 4 [chart], (Saucesian, Los Sauces Creek, Ventura Co., Calif.).

Description: Test free, small, trochospiral, unevenly biconvex, spiral side lower than umbilical side, outline circular, periphery subacute. Spiral side flattened, raised in apical region by thick deposits of calcite which obscure early whorls and chambers. Umbilical side sharply convex, acute in umbilical area, umbilicus covered by deposits of clear calcite, 6 to 9 chambers visible in last whorl. Chambers rhomboid to lunate on spiral side, trigonal, slightly inflated and overlapping previous whorl on umbilical side. Sutures distinct, limbate, wide, flush with test surface, radial, curved back slightly. Wall calcareous, smooth, thickened in axial regions, finely perforate. Aperture a narrow vertical slit parallel to periphery, basal, occurring in depression on umbilical side of test, apertural face flattened, margin sharply rounded.

Discussion: The original illustrations of the holotype of *Pseudoparrella minuta* show six chambers in the last whorl, whereas the

specimen on the type slide has nine, hence this specimen may not be the holotype.

Pseudoparrella minuta is similar to some specimens of *P. subperuviana* but differs in the smaller size, more flattened spiral side, and thickened walls in the axial region. A large series of topotypes of both species show them to be distinct; *P. minuta* therefore is elevated to specific rank.

Type locality and occurrence: This species was originally described from lower Miocene Strata exposed in Los Sauces Creek, Ventura County, California. It has since been recorded from contemporaneous strata in the Santa Ynez Mountains and the southwestern San Joaquin Valley, California.

PSEUDOPARRELLA RELIZENSIS
(Kleinpell)
Pl. I, figs. 7a-8c

Pulvinulinella relizensis KLEINPELL, 1938, Miocene stratigraphy of California, p. 329, pl. 10, figs. 10a-c (upper Saucesian to upper Luisian, Reliz Canyon, Monterey Co., Calif.; Adelaida Quad., San Luis Obispo Co., Calif.). NATLAND, 1950, Geol. Soc. America, Mem. 43, pt. 4, p. 33, pl. 9, figs. 4a-c (Pliocene, Carmen Island, Baja California, Mexico).

Epistominella relizensis (Kleinpell). SMITH, P. B., 1960, U. S. Geol. Survey, Prof. Paper 294-M, p. 487 (Mohnian, Santa Ana Mts., San Juan Capistrano Area, Orange Co., Calif.).

Description: Test free, small to medium in size, biconvex, trochospiral, about 2½ whorls, outline circular to suboval, periphery rounded to subacute. Spiral side flattened, edges rounded, all chambers and proloculus visible. Umbilical side slightly convex, commonly depressed in umbilical area, about 9 chambers visible, umbilicus closed. Chambers about 21 in number, slightly inflated, each curved back over that preceding, chambers rhomboid and slightly overlapping those of previous whorl on spiral side, chamber height on spiral side 2 to 3 times the width, on umbilical side chambers are wedge-shaped, narrow at base, widening at top and with flattened umbilical extension, proloculus round. Sutures distinct, thin, slightly depressed and curved backwards. Wall calcareous, smooth, finely perforate. Aperture basal, narrow, elongate vertical slit parallel to periphery, equatorial or slightly on umbilical side of test, depressed, bordered by very narrow rim.

Discussion: The holotype of this species was deposited at Stanford University but is no longer in the collections according to A. Myra Keen and J. J. Graham.

The aperture of *P. relizensis* varies in position from peripheral to extraumbilical. The final chamber of some specimens is shortened (Pl. 1, fig. 7a-c), as in the holotype.

Pseudoparrella relizensis resembles *Megastomella* in its commonly equatorial aperture and curved sutures. It is placed in *Pseudoparrella* because of the short rhomboid chambers, circular to suboval outline, and biconvex test.

The species is distinguished from *P. subperuviana* by the more rounded periphery, more evenly biconvex test, and nearly peripheral aperture. It is separated from *P. californica* by the larger size, relatively thinner test and chambers, and curved sutures.

Type locality and occurrences: The type locality of *P. relizensis* is on a ridge projecting east, approximately 3800 feet northeast of the Reliz Canyon Camp Ground, Reliz Canyon, Monterey County California. It is "580 feet above the top of the Vaqueros sandstone" (Kleinpell, 1938, p. 330) in the Monterey Shale of the middle Relizian stage. *Pseudoparrella relizensis* occurs abundantly in Reliz Canyon. It is reported from upper Miocene rocks in Orange County, Calif., and from Pliocene sediments of Carmen Island, Baja California, about 850 miles south of the type locality.

PSEUDOPARRELLA SUBPERUVIANA
(Cushman)
Pl. I, figs. 1a-3c

Pulvinulinella subperuviana CUSHMAN, 1926, Cushman Lab. Foram. Res., Contr., vol. 2, pt. 3, p. 63, pl. 9, figs. 9a-c (middle Miocene, Highland District, San Luis Obispo Co., Calif.). CUSHMAN, STEWART and STEWART, 1930, San Diego Soc. Nat. Hist., Trans., vol. 6, no. 2, p. 73 (middle Miocene, Bear River, Humbolt Co., Calif.). DORN, 1932, Micropaleontology Bull., Stanford, vol. 3, no. 2, p. 29 (Miocene, Salinas Valley, Calif.). WOODRING, BRAMLETTE and KLEINPELL, 1936, Amer. Assoc. Petrol. Geol., Bull., vol. 20, no. 2, p. 133 (middle Miocene, Palos Verdes Hills, Calif.). KLEINPELL, 1938, Miocene stratigraphy of California, p. 330 (lower Saucesian to upper Luisian, Nipomo Quad., San Luis Obispo Co.; Chico Martinez Creek, Kern Co.; Carneros Creek, Kern Co.; Concord Quad., Contra Costa Co., Calif.). WOODRING, BRAMLETTE and LOHMAN, 1943, Amer. Assoc. Petrol. Geol., Bull., vol. 27, no. 10, p. 1344, 1346 (Relizian, Santa Maria District, Santa Barbara Co., Calif.). KLEINPELL *in* Woodring, Bramlette and Kew, 1946, U. S. Geol. Survey, Prof. Paper 207, p.

19 [table] (Miocene, Palos Verdes Hills, Calif.).

Pulvinulinella bradyana CUSHMAN, 1927, Univ. Calif., Scripps Inst. Oceanogr., Bull., Tech. ser., vol. 1, no. 10, p. 165, pl. 5, figs. 11-13 (Recent, off Panama). ADAMS, 1932, Micropaleontology Bull., Stanford, vol. 3, no. 4, lists, p. 24 (Pliocene, Orange Co., Calif.). NATLAND, 1933, Univ. Calif. Scripps Inst. Oceanogr., Bull., Tech. ser., vol. 3, no. 10, chart (Recent, San Pedro Channel; Pliocene, Hall Canyon, Ventura Co., Calif.). NATLAND, 1950, Geol. Soc. America, Mem. 43, pt. 4, p. 33, pl. 9, figs. 3a-c (Pliocene, Carmen Island, Baja California).

Pseudoparrella subperuviana (Cushman). CUSHMAN and STEVENSON, 1948, Cushman Lab. Foram. Res., Contr., vol. 24, pt. 3, p. 65, pl. 10, figs. 24, 25 (lower Miocene, south side of Caraquez Bay, Ecuador). CUSHMAN, STEWART and STEWART, 1949, Oregon Dept. Geol. and Mineral Indust., Bull. 36, pt. 7, p. 154, pl. 18, figs. 1a-c (Pliocene, near mouth of Quinault River, Grays Harbor Co., Washington). CROUCH, 1951, Cushman Found. Foram. Res., Contr., vol. 2, pt. 2, p. 10 (lower Pliocene, Newport Lagoon, Calif.).

Pseudoparrella bradyana (Cushman). MARTIN, 1952, Cushman Found. Foram. Res., Contr., vol. 3, pt. 3-4, p. 116, table 3.

Epistominella bradyana (Cushman). MARTIN, 1952, Cushman Found. Foram. Res., Contr., vol. 3, pt. 3-4, p. 136, pl. 24, figs. 9a-c (Pliocene, Los Angeles Basin). WHITE, 1956, Jour. Paleontology, vol. 30, no. 2, p. 257, pl. 31, figs. 7a-c (Pliocene, Capistrano Beach area, Calif.). BANDY and ARNAL, 1957, Amer. Assoc. Petrol. Geol., Bull., vol. 41, no. 9, p. 2041, 2042, 2051 [tables] (Recent, off Central America). RESIG, 1958, Micropaleontology, vol. 4, no. 3, p. 306 (Recent, Santa Cruz Basin, Calif.). ZALESNY, 1959, Micropaleontology, vol. 5, no. 1, p. 124 (Recent, Santa Monica Bay). MCGLASSON, 1959, Micropaleontology, vol. 5, no. 2, p. 236 (Recent, off Santa Catalina Island, Calif.). RESIG, 1959, State Water Pollution Control Board, Calif., publ. 20, pt. VI, p. 448. BANDY and ARNAL, 1960, Amer. Assoc. Petrol. Geol., Bull., vol. 44, no. 12, p. 1927. BANDY, 1961, Micropaleontology, vol. 7, no. 1, p. 15, table 1, pl. 3, figs. 16a-b (Recent, Gulf of California). SMITH, P. B. *in* Winterer and Durham, 1962, U. S. Geol. Survey, Prof. Paper 334-H, p. 288, 295, 313, pl. 48, 49 [tables] (upper Miocene to Pliocene, Southeast Ventura Basin, Calif.). NATLAND, 1963, Jour. Paleontology, vol. 37, no. 4, p. 949 [table] (upper Pliocene, Hall Canyon, Ventura Co., Calif.). HARMAN, 1964, Micropaleontology, vol. 10, no. 1, p. 95 (Recent, Santa Barbara Basin, Calif.). BANDY, 1964, Jour. Paleontology, vol. 38, no. 1, p. 141 (Recent, Santa Monica and San Pedro Basins, Calif.). BANDY, INGLE and RESIG, 1964, Limnology and Oceanography, vol. 9, no. 1, p. 118, 120 (Recent, off Laguna Beach, Calif.). BANDY, INGLE and RESIG, 1964, Geol. Soc. America Bull., vol. 75, no. 5, p. 419, text-fig. 10, H, no. 3 (Recent, San Pedro Bay, Calif.). SMITH, P. B., 1964, U. S. Geol. Survey Prof. Paper 429-B, p. B43, pl. 4, figs. 5a, b (Recent, off El Salvador). BANDY and RODOLFO, 1964, Deep-Sea Res., vol. 11, no. 5, table 3 (Recent, Peru-Chile Trench).

Epistominella subperuviana (Cushman). PIERCE, 1956, Jour. Paleontology, vol. 30, no. 6, p. 1300, pl. 140, figs. 1a-c (Mohnian, Benedict Canyon, Los Angeles Co., Calif.). SMITH, P. B., 1960, U. S. Geol. Survey, Prof. Paper 294-M, p. 487 (upper Luisian to lower Mohnian, Santa Ana Mts. and San Juan Capistrano areas, Calif.). BANDY and ARNAL, 1960, Amer. Assoc. Petrol. Geol., Bull., vol. 44, no. 12, p. 1927 (Miocene, southern San Joaquin Valley, Calif.). SMITH, P. B. *in* Winterer and Durham, 1962, U. S. Geol Survey, Prof. Paper 334-H, p. 288, 295, 313, pl. 48, 49 [tables] (upper Miocene to Pliocene, southeastern Ventura Basin, Calif.). LOEBLICH and TAPPAN, 1964, Treatise Invert. Paleontology, pt. C, Protista 2, vol. 2, p. C578, fig. 453, no. 5a-c (Holotype refigured).

Epistominella subperuviana subperuviana (Cushman). BANDY and KOLPACK, 1963, Micropaleontology, vol. 9, no. 2, p. 153 (Refugian to Mohnian, Tecolote Tunnel, Santa Ynez Mts., Santa Barbara Co., Calif.).

NOT *Pulvinulinella subperuviana* Cushman. SACAL and DEBOURLE, 1957, Soc. Géol. France, Mém., no. 78, p. 47, pl. 21, fig. 1.

Description: Test free, trochospiral, medium in size, inequally biconvex, about 2½ whorls, outline circular to slightly oval, periphery acute. Spiral side convex, flattened on last whorl, raised in center, all whorls and chambers visible. Umbilical side evenly convex, commonly depressed in center, umbilicus closed, covered by chamber extensions. Chambers about thirty in number, ten in last whorl, increasing in relative height with growth, about half as wide as high, narrow in axial region becoming wider at margin on umbilical side, with extension toward but not always covering umbilicus, proloculus circular. Sutures distinct, thin, slightly raised, curved smoothly backward. Wall calcareous, smooth, finely perforate, early whorls thickened and opaque when dry, last whorl thinner and translucent, crystal structure radial, septa monolamellid. Aperture a very narrow slit, parallel to periphery, on umbilical side of last chamber, elongate, extending from base to near top of chamber, depressed in apertural face, bordered by a very narrow rim.

Discussion: The holotype (Pl. 1, figs. 1a-c) of *Pseudoparrella subperuviana* is damaged. Its final chamber is missing and one

of the remaining chambers is broken on the spiral side (not shown on Pl. 1). Material remaining from the broken final chamber gives the apertural face a more pronounced and wide appearance. The holotype of *P. bradyana* (Pl. 1, figs. 3a-c) is identical to topotype specimens of *P. subperuviana.*

This species is characterized by its flattened final whorl, acute periphery, moderately large size, and limbate sutures. The aperture is always definitely on the umbilical side of the test. In some specimens the apex of the spire is more elevated and the final whorl more flattened, and the sutures on the umbilical side of the test may curve back.

Sacal and Debourle (1957) figured *P. subperuviana* from the Aquitaine Basin in France, but their specimen does not belong to *Pseudoparrella,* the aperture being typical of *Alabamina.*

Type locality and occurrences: Pseudoparrella subperuviana was originally described from Luisian rocks in Sec. 24, T.28S., R.14E., Mt. Diablo Base and Meridian, Highland District, San Luis Obispo County, California. *P. bradyana* was described from Recent sediments at Latitude 7°01′N and Longitude 81°48.7′W off Panama, Central America.

The species occurs from Washington southward to Ecuador in deposits ranging from Oligocene (?) to Recent. In general, specimens from Pliocene or younger rocks were previously designated *P. bradyana,* whereas those from older rocks were called *P. subperuviana.*

PSEUDOPARRELLA? DISCORBISOIDES
(Pierce)
Pl. I, figs. 10a-c

Epistominella discorbisoides PIERCE, 1956, Jour. Paleontology, vol. 30, no. 6, p. 1304, pl. 139, figs. 13 (Mohnian, Benedict Canyon, Los Angeles Co., Calif.).

Description: Test free, trochospiral, of medium size, inequally biconvex, about 2½ whorls, outline circular, periphery acute, carinate. Spiral side strongly convex, tending to become flattened on last whorl, all whorls, chambers and proloculus visible. Umbilical side flattened to very slightly convex, depressed in umbilical area, only last whorl visible. Chambers lunate on spiral side, slightly inflated and partially covering previous whorls on umbilical side, increasing rapidly in relative height with growth. Sutures curved slightly back on spiral side, initially directed forward then strongly curved back on umbilical side. Wall calcareous, smooth, finely perforate, crystal structure radial. Aperture a narrow basal slit parallel to periphery on umbilical side of test.

Discussion: The type slide of this species contained the holotype, three paratypes and one *Buccella.* As the final chambers of all specimens were broken away and the apertural region damaged, the apertural characters are not clear. Additional specimens could not be found in samples collected from the type area nor in samples provided by R. L. Pierce.

The generic assignment of these specimens is questionable. The microstructure of the test could not be completely determined as the technique for determining lamellar characters of the septa requires sectioning, and only type material was available. The specimens were studied with polarized light, which revealed a radial crystalline wall structure. The species is tentatively assigned to *Pseudoparrella* because of similarities to aberrant specimens of *P. subperuviana* from the Monterey Formation near Carmel, California. The type specimens of *P. discorbisoides* may actually represent aberrant *P. subperuviana.*

Type locality: The type locality of *P. discorbisoides* was not precisely stated in the original description. The type slide is labeled USC 261 which corresponds to Pierce's locality 100. It is approximately 200 feet north of Mulholland Drive on the Davana Fire Road. The species was listed from 11 samples ranging from lower to upper Mohnian, from Benedict Canyon, Los Angeles County, California (Pierce, 1956).

Genus STETSONIA F. L. Parker
STETSONIA MINUTA F. L. Parker
Pl. II, figs. 8a-c

Stetsonia minuta F. L. Parker, 1954, Mus. Comp. Zool., Harvard, Bull., vol. 111, no. 10, p. 534, pl. 10, figs. 27-29.

Description: Test free, small, involute in later stages, slightly trochospiral in early stage, biconvex, outline nearly circular, lobate, periphery rounded. Chambers of last whorl 10, completely overlapping previous whorls, crescent-shaped, increasing in height with growth, slightly inflated, overlapping front of previous chamber. Sutures distinct, thin, depressed, curved smoothly back. Wall calcareous, smooth, finely perforate, thin, crystalline structure radial, septa monolamellid. Aperture a narrow slit extending from base of face to top of last chamber, depressed, tending to slant toward one side of test, bordered by narrow rim, apertural face rounded.

Discussion: This species, the type for the genus, differs from *S. horvathi* Green in having nearly twice as many chambers in the last whorl and a slightly asymmetrical aperture.

Type locality: Stetsonia minuta was described from the northeastern part of the Gulf of Mexico at Latitude 29°40′N, Longitude 88°28.5′W, at a depth of 42 m. It occurs in samples taken in 20 to 3251 m.

Genus EILOHEDRA Lipps
EILOHEDRA LEVICULA (Resig)
Pl. III, figs. 5a-c, text-fig. 3

Epistominella levicula RESIG, 1958, Micropaleontology, vol. 4, no. 3, p. 304, text-figs. 16a-c (Recent, Santa Cruz Basin, Calif.). MCGLASSON, 1959, Micropaleontology, vol. 5, no. 2, p. 236 (Recent, off Santa Catalina Island, Calif.). BANDY, 1961, Micropaleontology, vol. 7, no. 1, p. 15 (Recent, Gulf of California). BANDY and RODOLFO, 1964, Deep-Sea Res., vol. 11, no. 5, table 4, fig. 5a (Recent, Peru-Chile Trench).

Eponides leviculus (Resig). UCHIO, 1960, Cushman Found. Foram. Res., Spec. publ. no. 5, p. 67, pl. 10, figs. 23-25 (Recent, off San Diego, Calif.). PHLEGER, 1964, Amer. Assoc. Petrol. Geol., Mem. 3, p. 383, pl. 2, figs. 20, 21 (Recent, Gulf of California).

Eponides sp. A. CROUCH, 1952, Amer. Assoc. Petrol. Geol., Bull., vol. 36, no. 5, p. 836, pl. 5, figs. 10-11 (Recent, East Cortes, Long Basins, off Southern California; Pliocene, Los Angeles Basin, Calif.).

Description: Test free, small, inequally biconvex, trochospiral, outline circular, slightly lobate, periphery rounded. Spiral side strongly convex, all whorls, chambers and proloculus visible. Umbilical side slightly convex, depressed in umbilical area, only last whorl visible around the open umbilicus. Chambers slightly inflated, curved back over that preceding, rhomboid to rectangular in spiral view, trigonal in umbilical view, broadly rhomboid in edge view. Sutures distinct, thin, slightly depressed, radial, directed straight back on spiral side, arched back on umbilical side. Wall calcareous, finely perforate, thin, transparent, surface smooth, crystalline structure radial, septa bilamellid. Aperture basal, low, extending from near umbilicus to near periphery, with short vertical extension up face of final chamber near periphery, depressed.

Discussion: This species is distinguished from similar species in other genera by its characteristic aperture, small size, and numerous chambers.

Type locality and occurrences: Eilohedra levicula was originally described from Recent deposits in Santa Cruz Basin, off California, but an exact locality was not given.

The species occurs between 42 and 5929 m and is most abundant in deeper waters below sill depth in basins off Southern California. It also is reported living between 122 and about 565 m in the Gulf of California, and as fossil from the Pliocene of the Los Angeles Basin. *Eilohedra levicula* is reported from the Peru-Chile Trench off South America.

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March 15, 1965

PLATES I-III

All Figures: a, Spiral View; b, Umbilical View; and c, Apertural View. All are shaded camera lucida drawings.

Abbreviations: UCLA=Type collections, Department of Geology, University of California, Los Angeles; USNM=U. S. National Museum; USC=University of Southern California.

Plate I

Figures Page

1. *Pseudoparrella subperuviana* (Cushman) 135
   Holotype Cushman Coll. (USNM) 5825, Luisian, Highland District, California. Note broken final chamber. x125.

2. *Pseudoparrella subperuviana* (Cushman) 135
   Topotype UCLA 34751, Luisian, Highland District, California. Showing complete specimen. x66.

3. *Pseudoparrella subperuviana* (Cushman) 135
   Holotype, USNM 20302, of *Pulvinulinella bradyana* Cushman. Recent, off Panama, Lydonia Station 30, Lat. 7°01′N, Long. 81°48.7′W. x66.

4. *Pseudoparrella garrisoni* Lipps, nom. nov. 134
   Holotype, UCLA 34799, Saucesian, 2950 to 2976 cored interval, Seaboard-Welsh no. 1 well, north of Coalinga, California. x156.

5. *Pseudoparrella minuta* (Cushman and Laiming) 134
   Topotype, UCLA 34752, Saucesian, Rincon Shale, Los Sauces Creek, California. x143.

6. *Pseudoparrella californica* (White) 132
   Topotype, UCLA 34753, Miocene-Pliocene, Capistrano Beach, California. x143.

7. *Pseudoparrella relizensis* (Kleinpell) 135
   Hypotype, UCLA 34754, Saucesian, Reliz Canyon, California, showing short aperture similar to holotype. x143.

8. *Pseudoparrella relizensis* (Kleinpell) 135
   Hypotype, UCLA 34755, Saucesian, Reliz Canyon, California, showing longer typical aperture. x100.

9. *Pseudoparrella exigua* (Brady) 133
   Holotype, USNM 626812, of *Epistominella sandiegoensis* Uchio, Recent, off San Diego, California, Lat. 32°23.2′N, Long. 117°19.5′W. x143.

10. *Pseudoparrella? discorbisoides* (Pierce) 137
    Paratype, USC 3586A, Mohnian, Benedict Canyon, Los Angeles, California. x87.

11. *Ambitropus evax* (Bandy) 124
    Paratype, USC 1044A, Recent, Cordell Bank off San Francisco, California. x66.

Drawings: Figs. 2, 4, 6-8, 11 by Margaret Rogers; 3, 5, 9-10 by Helen Tappan Loeblich; 1 by Lawrence B. Isham.

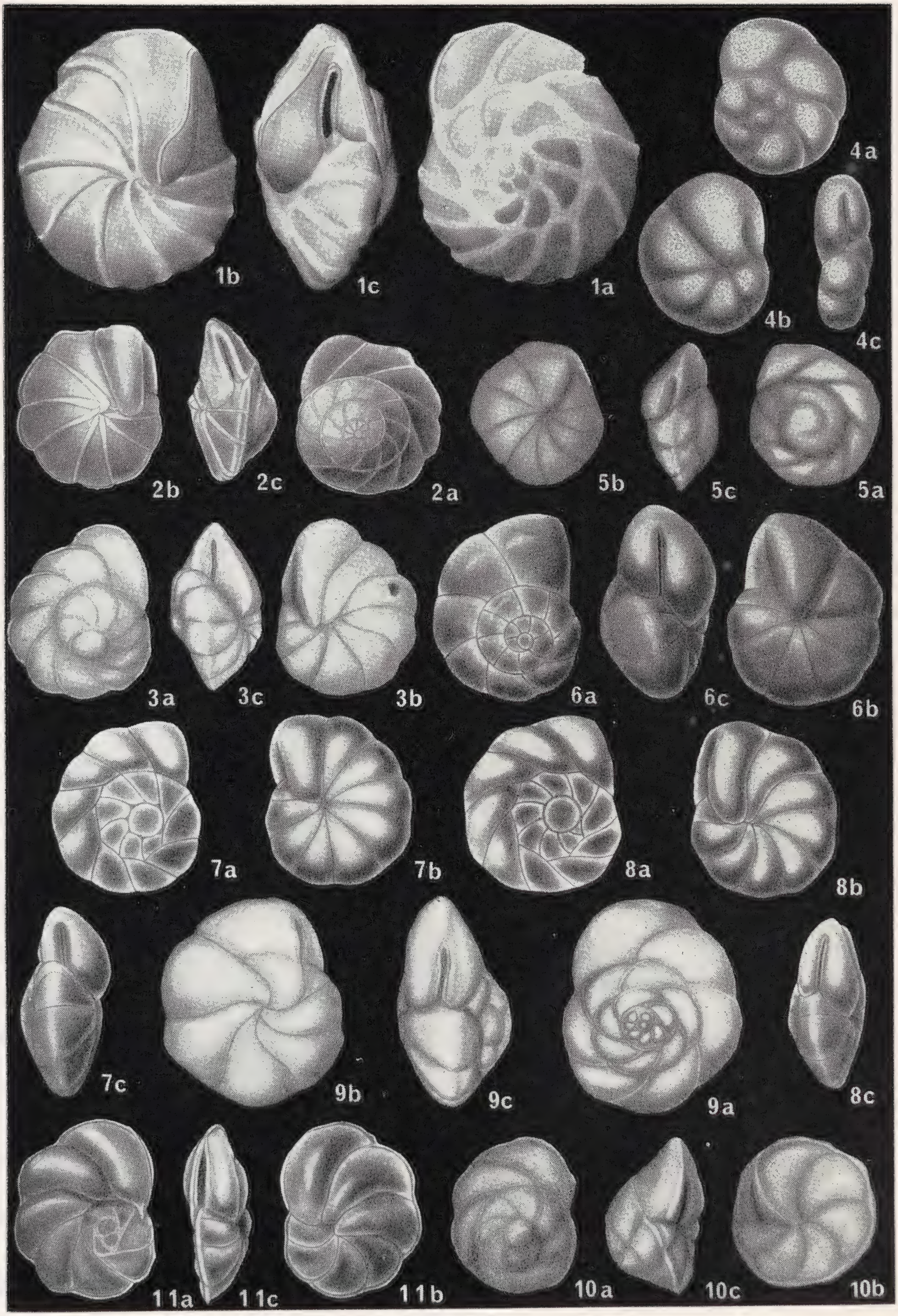
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PLATE I

Plate II

Figures

1. *Concavella gyroidinaformis* (Cushman and Goudkoff) ---- 125
Hypotype, UCLA 34756, lower Mohnian, east side of Newport Bay, California, showing typical basal aperture and concave spiral side. x100.

2. *Concavella gyroidinaformis* (Cushman and Goudkoff) ---- 125
Hypotype, UCLA 34757, middle Mohnian, east side of Newport Bay, California, showing areal aperture and final chambers tending to become uniserial. x50.

3. *Concavella gyroidinaformis* (Cushman and Goudkoff) ---- 125
Hypotype, UCLA 34758, lower Mohnian, east side of Newport Bay, California, showing strongly concave spiral side. x100.

4. *Epistominella pulchella* Husezima and Maruhasi ---- 129
Hypotype, UCLA 34764, Pliocene, Haizume Formation, Niigata Prefecture, Japan. x66.

5. *Epistominella pacifica* (Cushman) ---- 126
Hypotype, UCLA 34759, Luisian, Highland District, San Luis Obispo County, California. This specimen was compared with the holotype of *Pulvinulinella parva* and is identical to it. x140.

6. *Epistominella smithi* (Stewart and Stewart) ---- 129
Holotype, Cushman Coll. (USNM) 12545, Pliocene, Ventura, California. x66.

7. *Epistominella pacifica* (Cushman) ---- 126
Holotype, USNM 20301, Recent, off California, Discoverer station 19J, Lat. 36°50′N, Long. 122°15′W. x66.

8. *Stetsonia minuta* F. L. Parker ---- 137
Paratype, UCLA 34760, Recent, northeast Gulf of Mexico, Lat. 29°40′N, Long. 88°28.5′W. x283.

Drawings: Figs. 1-4, 7 by Margaret Rogers; 5-6 by Helen Tappan Loeblich; 8 by Lawrence B. Isham.

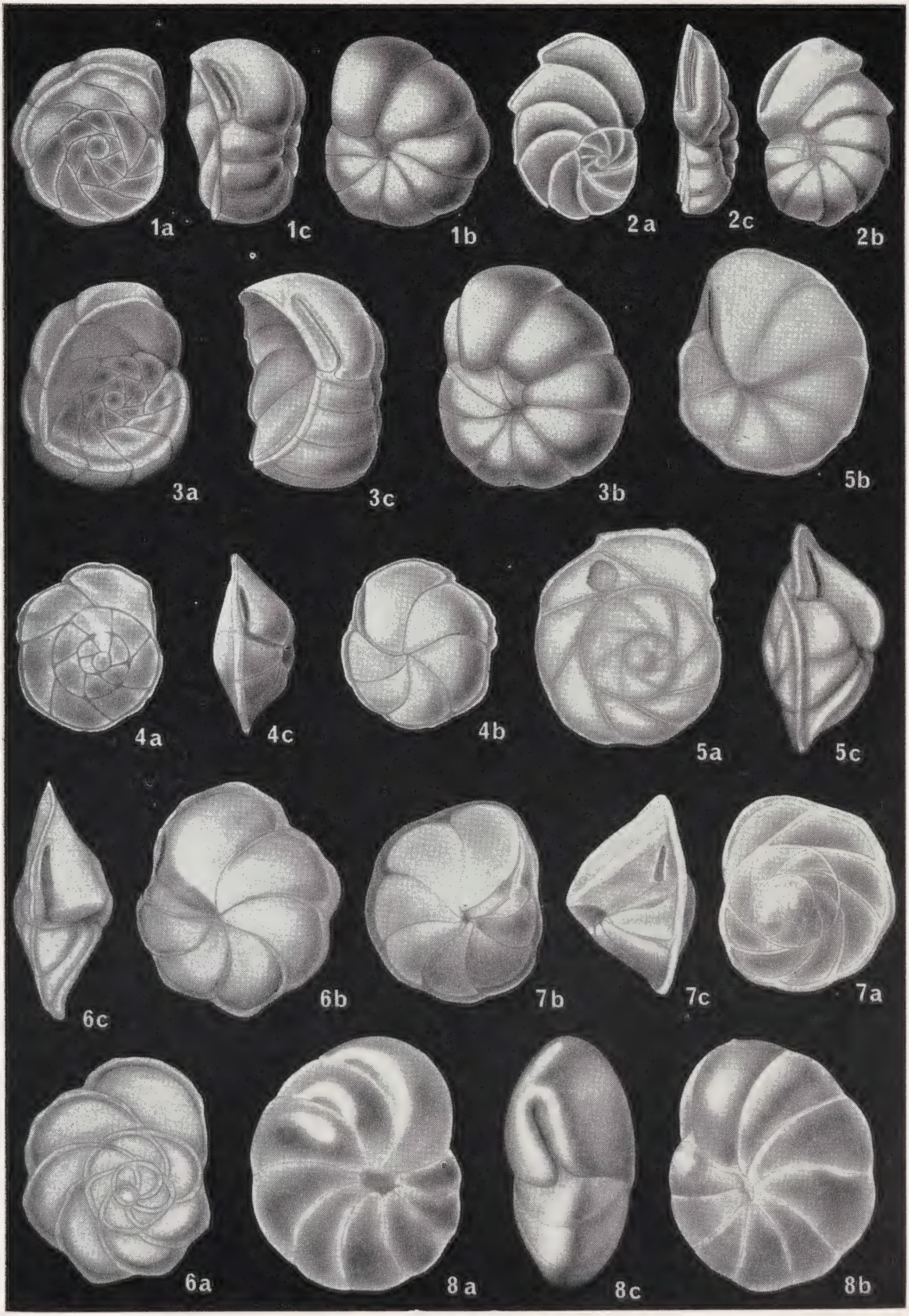

PLATE II

Plate III

Figures Page

1. *Megastomella capitanensis* (Cushman and Kleinpell) 131
   Holotype, Cushman Coll. (USNM) 20149, lower Mohnian, west of Naples, Santa Barbara County, California. x87

2. *Megastomella capitanensis* (Cushman and Kleinpell) 131
   Hypotype, UCLA 34761, lower Mohnian, east side of Newport Bay, California. x93

3. *Megastomella africana* Faulkner, de Klasz and Rérat 131
   Topotype, UCLA 34762, lower Miocene, Gabon Basin, Africa. x46.

4. *Megastomella purisima* (Bramlette) 132
   Holotype, USNM 560221, late upper Miocene, near Woodland Hills, California. x53

5. *Eilohedra levicula* (Resig) 138
   Hypotype, UCLA 34763, Recent, off San Diego, California. x280.

Drawings: Figs. 1, 5 by Helen Tappan Loeblich; 2-4 by Margaret Rogers.

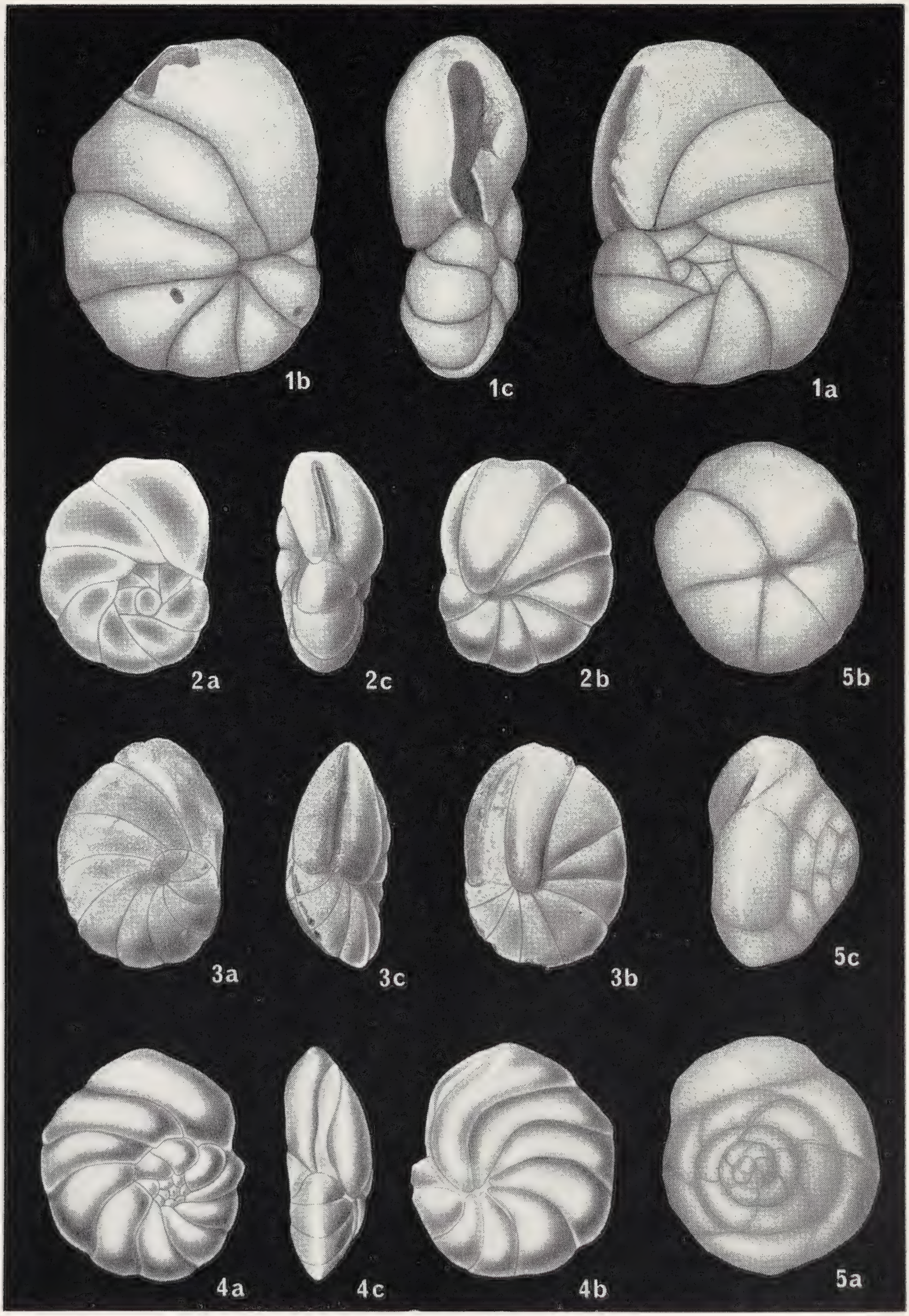

PLATE III

ERRATA

(continued from page 116)

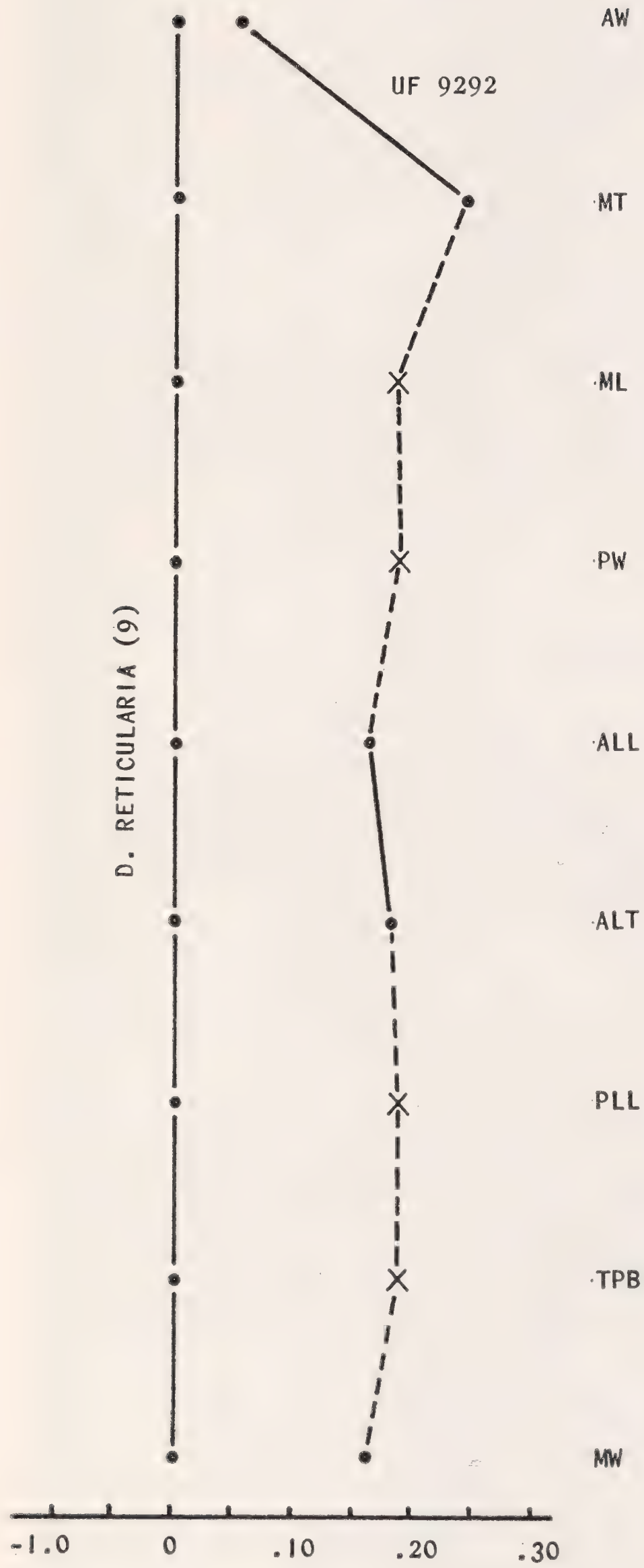

Figure 2. Ratio diagram comparing various dimensions of fossil *Deirochelys* (UF 9292) and a series of Recent *D. reticularia*. Abbreviations same as in Fig. 1. X = estimated dimension.

VOLUME 3

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No. 1—page 75, plate VI. Figures 28 and 29 are reversed.

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TAXONOMIC REVISION OF CERTAIN DISCORBACEA AND ORBITOIDACEA (FORAMINIFERIDA)

ROBERT DOUGLAS and WILLIAM V. SLITER
DEPARTMENT OF GEOLOGY
UNIVERSITY OF CALIFORNIA, LOS ANGELES p. 149

PHOTOMETRIC DETERMINATION OF PREFERRED ORIENTATION OF FELDSPARS IN FINE-GRAINED IGNEOUS ROCKS

JOSEPH D. MARTINEZ
ASSOCIATE PROFESSOR OF GEOLOGY
NORTHERN ILLINOIS UNIVERSITY p. 165

CENOZOIC VERTEBRATES FROM THE GULF COASTAL PLAIN—I

ANDREW A. ARATA and CRAWFORD G. JACKSON, JR.
TULANE UNIVERSITY AND
UNIVERSITY OF SOUTH ALABAMA p. 175

REVIEWS: THE FABRIC OF GEOLOGY; THE FOUNDERS OF GEOLOGY; ILLUSTRATIONS OF THE HUTTONIAN THEORY OF THE EARTH

HUBERT C. SKINNER
PROFESSOR OF GEOLOGY
TULANE UNIVERSITY p. 179

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ROBERT DOUGLAS and WILLIAM V. SLITER[1]
DEPARTMENT OF GEOLOGY
UNIVERSITY OF CALIFORNIA, LOS ANGELES

CONTENTS

Page

I. ABSTRACT 149
II. INTRODUCTION 150
III. MATERIALS AND METHODS 150
IV. ACKNOWLEDGMENTS 151
V. SYSTEMATIC DESCRIPTIONS 151
A. *Discorbis* 151
B. *Rotorbinella* 152
C. *Trochulina* 154
D. *Rosalina* 155
VI. CONCLUSIONS 158
VII. REFERENCES 160
PLATE 1 159
PLATE 2 161
PLATE 3 163

I. ABSTRACT

Taxonomic revision of genera of two superfamilies of Foraminiferida, the Discorbacea and Orbitoidacea, is presented. The classification adopted in this paper is based on wall structures, life cycles, and morphology of the test. Descriptions are based on type material or living specimens grown under laboratory conditions.

Discorbis vesicularis Lamarck is shown to be monolamellar. The genus *Rotorbinella* Bandy is reinstated and placed in the Discorbinae and includes *Gavelinopsis* Hofker, and *Biapertorbis* Pokorný as synonyms. *Rotorbinella campanulata* (Galloway and Wissler) includes the following as specific synonyms: *Globorotalia campanulata* Galloway and Wissler, *Rotalia turbinata* Cushman and Valentine, *R. vesiformis* Bandy, *R.* spp. Walton, *R. avalonensis* Natland, and *Rosalina campanulata* Uchio.

[1] Names arranged alphabetically, no seniority implied.

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Trochulina d'Orbigny is bilamellar, removed from the Discorbinae and reinstated in the family Eponididae, superfamily Orbitoidacea.

Tretomphalus Möbius is a junior synonym of *Rosalina* d'Orbigny. *R. globularis* d'Orbigny is bilamellar and placed in the family Rosalinidae, of the Orbitoidacea. Synonyms of *R. globularis* include: *Discorbis columbiensis* Cushman, *D. monicana* Zalesny, *Tretomphalus myersi* Cushman, *T. bulloides* (d'Orbigny), *Rosalina bulloides* d'Orbigny, and *Discorbis isabelleana* (d'Orbigny) (?) Cushman and Valentine. *Rosalina mira* (Cushman) and *R. subbertheloti* (Cushman) are regarded as distinct species. *Discorbis floridana* Cushman is considered to be a glabratellid.

II. Introduction

Two excellent taxonomic studies of the Foraminiferida have recently appeared in the literature (Reiss, 1963; Loeblich and Tappan, 1964a). The classifications presented in these studies have been based primarily upon test morphology, emphasizing in particular the wall structure and methods of reproduction. While these revisions add to our knowledge of these protozoans, they, at the same time, point out the current limited state of knowledge of life cycles and genetic studies as well as the lack of definitive information on the wall structure of many genera. In 1962 the present writers began a study of living West Coast foraminifers with the hope of obtaining a better understanding of the organisms and of perhaps gaining information applicable to the investigation of their fossil representatives. This paper summarizes one aspect of the work now in progress and is an attempt at a more complete paleontologic-biologic approach to the foraminiferal taxonomy of a group of species.

Shortly after laboratory cultures of foraminifers were initiated, *Rosalina globularis* was selected for life cycle and ecologic studies, and at that time a routine identification was attempted. It soon became apparent that this species and another, *Rotorbinella campanulata,* previously had been assigned to several genera and species, thus obscuring the geographic distribution, the known range of morphologic variation, and the systematic affinities. Different stages in the life cycle of *Rosalina globularis* were also referred to separate genera, along with conflicting data on the mode of reproduction. Utilizing information gained from life studies, wall structure, and comparison with type specimens, certain revisions of systematic placement are proposed.

III. Methods and Materials

This study is based on specimens from many different localities and type material from various organizations. The holotypes of *Tretomphalus myersi* Cushman, *T. clarus* Cushman, *T. pacificus* Cushman, *T. atlanticus* Cushman, *Rotalia turbinata* Cushman and Valentine, *R. avalonensis* Natland, *Discorbis columbiensis* Cushman, *D. mira* Cushman, *D. floridana* Cushman, and *D. subbertheloti* Cushman and plesiotypes of *Rosalina globosa* Todd and Low, and *Discorbis isabelleana* (d'Orbigny) (?) Cushman and Valentine were loaned for study by the U. S. National Museum. Holotypes of *Discorbis monicana* Zalesny, *Rotalia lomaensis* Bandy, and *R. versiformis* Bandy were loaned from the type collection by the University of Southern California, Los Angeles. Specimens of *Discorbis vesicularis* and *Trochulina turbo* were picked from samples collected at Mécrings, near Montmirant (Locality UCLA 4448), France. Hypotypes of *Rosalina globularis* from the Ross Sea, Antarctica, *Gavelinopsis praegeri* (Heron-Allen and Earland) from the Sahul Shelf, N. W. Australia, topotypes of *Rotorbinella colliculus* Bandy, and samples of the Calcaire grossier (Zone IV of Abrard), Grignon, France, were obtained from the Loeblich Collection. Recent examples of *Rosalina globularis* d'Orbigny and *Rotorbinella campanulata* (Galloway and Wissler) were collected from along the southern California coast and from the living cultures maintained by the writers at the University of California, Los Angeles, Department of Geology.

Laboratory cultures of *Rosalina globularis* and *Rotorbinella campanulata* were grown in 30 gallon circulating aquaria, at about 18°C, upon fronds of *Corallina officinalis* (Harvey), and in 100 ml agnotobiotic cultures. Agnotobiotic cultures with one species of diatom and foraminifer, and limited bacteria were maintained at various temperatures from 15°-23°C. Salinity in the cultures were adjusted to 34-35 $^{0}/_{00}$ using dis-

tilled water and seawater from Oceanarium, Inc., Marineland of the Pacific. PH was maintained at 7.5-8.5. Illumination was provided by cool-white, 15-watt fluorescent lamps supplying about 250 foot-candles on a 24 hour cycle.

Oriented thin-sections of specimens were made by arranging individuals on a glass slide with gum tragacanth glue and covering the specimen with Selectron 5003. The plastic was allowed to cure and then cut to standard thin-section thickness or slightly less.

The photomicrographs used in this paper were taken with a Zeiss Photomicroscope using Agfa 35 mm Isopan Iff black and white film and Polaroid black and white film. Specimens were originally photographed at magnifications, of 40X, 64X and 126X.

Cultures were routinely examined with a Leitz binocular stereoscopic microscope at magnifications of 25X, 50X, 100X and 150X. Cytology and thin sections were examined with an American Optical Co. Microstar binocular microscope at magnifications of 35X, 100X, 430X and 970X.

Shaded pencil drawings were made with the use of a Leitz camera lucida mounted on a Leitz binocular stereoscopic microscope.

All thin-sections used in this paper and the illustrated specimens of *Rosalina globularis* and *Rotorbinella campanulata* are on deposit in the Department of Geology, University of California, Los Angeles.

IV. Acknowledgments

The present studies were undertaken while both the writers were American Chemical Society Petroleum Research Fund Fellows, under the ACS PRF grant 979A2, awarded to Dr. Helen Tappan Loeblich, Department of Geology, University of California, Los Angeles.

The writers gratefully acknowledge the generous assistance of the following persons and organizations: Dr. Richard Cifelli, U. S. National Museum, for loan of type specimens; Dr. Orville Bandy, Department of Geology, University of Southern California, for loan of holotypes; Dr. John Lee, American Museum of Natural History, Living Foraminifera Laboratory, for loan of specimens; Dr. A. R. Loeblich, California Research Company, for use of photomicrographic equipment and use of personal specimens and samples; Dr. Helen Tappan Loeblich, Department of Geology, University of California, Los Angeles, for loan of type materials and for reading and criticism of the manuscript; Mr. John De Grosse, Department of Geology, University of California, Los Angeles, for preparation of the oriented thin-sections; and Mrs. Martha Matthews, scientific illustrator, for preparation of shaded camera-lucida drawings.

V. Systematic Descriptions

Superfamily Discorbacea Ehrenberg, 1838

Family Discorbidae Ehrenberg, 1838

Subfamily Discorbinae Ehrenberg, 1838

A. Genus Discorbis Lamarck, 1804

Discorbis Lamarck, 1804, Suite des mémoires sur les fossiles des environs de Paris: Muséum Natl. Histoire Nat. Paris, Ann., v. 5, p. 182, pl. 62.

Type species: *Discorbis vesicularis* Lamarck, 1804

Test free, trochospiral, plano-convex, all chambers visible on the spiral side, only chambers of final whorl visible on flattened umbilical side, with sutural openings extending from umbilicus towards margin, partly covered by flaps radiating from umbilical region; sutural openings connecting to interior of chamber cavity beneath flaps; primary aperture interiomarginal-extraumbilical; secondary sutural openings positioned on chamber flap opposite from primary aperture, remaining as relict openings in later chambers; biflagellate gametes, wall calcareous, perforate, radial in structure, septa monolamellid.

Remarks: Considerable uncertainty has surrounded the generic concept of *Discorbis* in the published literature because of poor illustration and description of the type species. This is vividly shown by the widely differing morphologic types which have been placed in this genus by different workers at various times. Lamarck's original figure of *D. vesicularis* did not clearly illustrate the diagnostic characters, particularly the features of the umbilical side. Later illustrations (Cushman, 1927) gave good spiral and side views but also failed to portray clearly the umbilical openings extending along the basal portion of the chambers and the flaps which radiate along the edge of these openings. This situation was resolved by Le Calvez (1949) and Loeblich and Tappan (1964a) who described and illustrated

topotype material. Despite these attempts to clarify the genus, disagreement about its basic morphology persists. Reiss (1963) states that based on examined topotypes of *D. vesicularis* the genus is bilamellar, and so placed the family Discorbidae within his Superfamily Bilamellidea. Glaessner (1963) concurred with the bilamellar structure stated by Reiss for the discorbids.

Based on the description and illustrations given by Le Calvez (1949) and Loeblich and Tappan (1964a) topotypes of *D. vesicularis* were isolated from samples of the Paris Basin Lutetian and sectioned by the writers to determine the lamellar structure. In contrast to the reports mentioned above the genus is monolamellar (plate 1, fig. 1a). This observation is in agreement with Hofker (1963) and Loeblich and Tappan (1964b).

It appears that the confusion as to the lamellar nature of the septa is a result of misidentification of *Trochulina turbo* and *D. vesicularis,* which frequently occur in the same samples. The adults of these species attain large size (up to 2 mm in diameter) and superficially resemble each other. Parker and Jones (1862), for example, in their discussion of the genus *Discorbis* illustrate d'Orbigny's model 73 of *Trochulina turbo* but describe features which characterize *D. vesicularis.* The two species are morphologically similar but are readily distinguished on the basis of their wall structure. *T. turbo* is clearly bilamellar (plate 2, figs. 1a, 1b).

B. Genus ROTORBINELLA Bandy, 1944

Rotorbinella BANDY, 1944, Jour. Paleontology, v. 18, p. 372, pl. 61, fig. 6.
Gavelinopsis HOFKER, 1951, Siboga Exped., pt. III, v. 8, p. 485.
Biapertorbis POKORNY, 1956, Univ. Carolina Geologica, v. 2, no. 3, p. 265, figs. 4-6.

Type Species: *Rotorbinella colliculus* Bandy, 1944

Test free, small, rotaloid, only last whorl visible ventrally, with definite umbilical plug; spire visible dorsally, this side usually much more convex than ventral side; chambers numerous, moderately or closely appressed; dorsal sutures flush, usually limbate, ventral sutures depressed, sometimes channeled, at times with reentrants; wall smooth, very coarsely perforate; aperture a slit at base of septal face, not extending onto periphery. (Original description, Bandy, 1944)

Remarks: To the above the writers add that the genus has a radial wall structure and monolamellar septa based on examination of topotypes.

The close similarity of this genus with other discorbid genera has been recognized by several authors (Hornibrook and Vella, 1954; Reiss, 1963). Most recently (Loeblich and Tappan, 1964a) *Rotorbinella, Biapertorbis,* and *Trochulina* (=*Discorbina*) were all placed in synonymy with the genus *Discorbis.* This reallocation was largely based on their general discorbid-like apertures, *i.e.,* an umbilical flap separating the primary aperture from secondary sutural openings. We agree with the previous workers as to the great degree of similarity between *Trochulina, Rotorbinella* and *Biapertorbis* but do not believe them all to be junior synonyms of *Discorbis.*

On the basis of wall characters and the basically similar apertural development, *Rotorbinella* is retained within the subfamily Discorbinae Lamarck. However, *Rotorbinella* is a high domed form, with a thickening at the apex of the spiral side and a solid central "column" which commonly projects as a knob or boss on the umbilical side. Discorbis in X-section is low, umbrella-shaped, without extensive secondary thickening on the spiral side and has no comparable central structure. Therefore, we recognize *Rotorbinella* as a distinct genus, and not a synonym of *Discorbis* Lamarck.

Pokorný (1956) described *Biapertorbis* from the Eocene of Czechoslovakia, placing great emphasis on the development of two apertures, one near the umbilical plug, the other half way between the periphery and the plug along the base of the frontal suture. The umbilical plug was indicated as either present or absent, although it is present in the type species. Pokorný remarked that *Rotorbinella* is comparable and that the "re-entrant" apertural features of *Rotorbinella* should be re-examined as they suggested a more specialized aperture than was described in the original diagnosis. Restudy of topotypes of *Rotorbinella* shows the congeneric relationship of the two genera. The development of the umbilical plug was disregarded as an important character by Pokorný, who stated that closely similar species may or may not possess this feature. We disagree, and believe the presence or absence of the umbilical plug cannot be determined merely by an external examination of the shell. We

believe the distinguishing features indicated by Pokorný are included in the generic description of *Rotorbinella* and for these reasons regard *Biapertorbis* as a junior synonym.

Gavelinopsis (Hofker) 1951 was first published as a *nomen nudum,* mentioning "*G. pacifica*" (then undescribed) as type species. Later the same year Hofker validated the genus, designating *Discorbina praegeri* Heron-Allen & Earland as type species. This genus is regarded as a synonym of *Rotorbinella* as no clear cut characters can be found to distinguish it from the latter (see also Reiss, 1963, p. 72). This conclusion is supported by thin-sections of hypotypes of *D. praegeri* from the Sahul Shelf which show the monolamellar nature of the septa. It should be noted that the specimens figured as *D. praegeri* by Hofker (figs. 332, 333, & 334, pp. 487, 488, and 489) differ from the illustrations of the original authors. Hofker's specimens are biconvex, with umbilical reentrants. The original type is convex-plano, with a prominent umbilical plug and a small slit aperture at the base of the final chamber. No mention was made of the special umbilical reentrants demonstrated by Hofker. The specimens examined and sectioned by the writers match the type of Heron-Allen and Earland.

ROTORBINELLA CAMPANULATA (Galloway and Wissler), 1927

Pl. 1, fig. 1; pl. 6, fig. 6

Globorotalia campanulata GALLOWAY and WISSLER, 1927, Jour. Paleontology, v. 1, p. 58, pl. 9, fig. 4.

Rotalia turbinata CUSHMAN and VALENTINE, 1930, Stanford Univ., Geology Contr., v. 1, no. 1, p. 25, pl. 7, figs. 1, 3.

Rotalia avalonensis NATLAND, 1950, Geol. Soc. America, Mem., 43, pt. 4, p. 30.

Rotalia lomaensis BANDY, 1953, Jour. Paleontology, v. 27, p. 179, pl. 22, fig. 6.

Rotalia versiformis BANDY, 1953, Jour. Paleontology, v. 27, p. 179, pl. 22, fig. 5.

Rotalia spp. WALTON, 1955, Jour. Paleontology, v. 29, p. 1014, pl. 103, figs. 18, 19, 24.

Rosalina campanulata (Galloway & Wissler) UCHIO, 1960, Cushman Found. Foram. Research, Spec. Publ. 5, p. 66, pl. 7, fig. 26.

Test trochoid or bell-shaped, composed of numerous whorls, dorsal side highly convex, ventral slightly concave or flat except for the last formed chamber which projects; peripheral margin rounded and limbate; chambers numerous, about six in the last volution; sutures nearly straight and tangent to the periphery of the previous coil dorsally, depressed ventrally and slightly irregular; umbilicus depressed or sometimes provided with a rounded knob of clear shell material; wall finely perforate; aperture an elongate slit extending into the umbilicus. Diameter of the type specimen, 0.23 mm; thickness 0.14 mm. (Original description, Galloway and Wissler, 1927).

Remarks: This species should be placed in *Rotorbinella* because of its plano-convex shape, definitive umbilical plug, limbate sutures and apertural characters. *R. campanulata* also has a radial, monolamellar wall structure. The quoted description above does not mention the secondary relict sutural openings which are present on most of the topotypes examined by the writers. Numerous specimens from the Lomita Quarry were oriented and thin-sectioned to examine the axial fillings. This structure is initiated at an early stage in the life of the individual and in extreme cases may occupy the major part of the test interior (see text-fig. 1d). In contrast to the plug developed by rotalids, which consists of many vertical pillars bound together, the filling is a single unit. All the specimens examined, both Recent and Pleistocene, contain this axial structure whether or not an external projection was developed. Described from the Pleistocene Lomita Marl, *R. campanulata* occurs in other Pleistocene deposits in California. Older occurrences are not known. The attached benthonic mode of life of this species produces individuals with a wide range of phenotypic variation in convexity of the test, the "keel" on the final whorl and the umbilical knob. Culturing this species in the laboratory has helped to demonstrate the conspecific nature of these variations although several names have been given to the different morphovariates. For example, the holotype of *Rotalia turbinata* closely matches one end member of the variation (see fig. 1d) while the holotype of *R. lomaensis* and *R. versiformis* fall within the range of variation shown by fig. 1b and 1c. Most Recent and Pleistocene examples of *Rotorbinella campanulata* compare closely to the forms illustrated by fig. 1b and 1c, but complete gradations from concavo-convex (fig. 1a) to unequally biconvex (fig. 1d) can be found whenever a large number of individuals are examined. The holotype and paratypes of *Discorbis monicana,* belong to different genera and species. The paratypes include specimens of

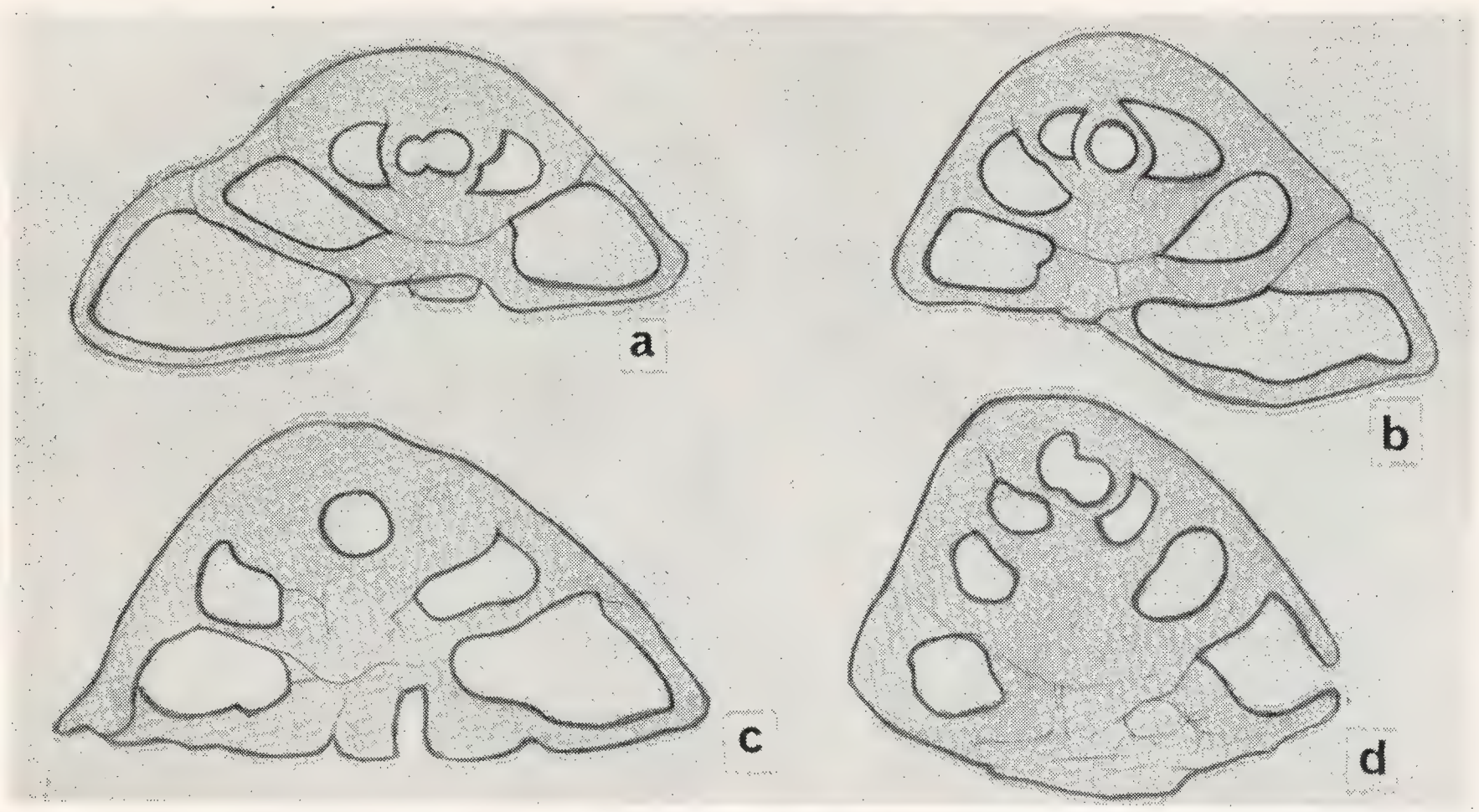

Figure 1. Axial sections of topotype specimens of *Rotorbinella campanulata* showing phenotypic variation in convexity of test. All X146.

both *Rotorbinella campanulata,* and *Rosalina globularis.* On the basis of many collections from localities along the California and Baja California coastline, we believe that several other species mentioned in papers on Recent Foraminifera from this area are also conspecific. However, few of these papers contain illustrations of their faunas and we have not examined all such types.

Range: The geographic range of this species is from Oregon, south to at least Punta Banda, Baja California, Mexico. It is a common intertidal form extending to about 10 fathoms. Within this zone it is most abundant on fronds of coralline algae, particularly *Corallina gracilis.* The distribution in deeper water is not as well documented. Uchio (1960) reports it living to 300 feet, with its greatest frequency at about 120 feet in the area off San Diego, California. Walton (1955) cites the range from 3 to 43 fathoms. Although it has been reported in much deeper water (Zalesny, 1959), information is not given to indicate if it was living at the time of collection at these depths.

Superfamily ORBITOIDACEA Schwager, 1876
Family EPONIDAE Hofker, 1951

C. Genus TROCHULINA d'Orbigny, 1839

Trochulina D'ORBIGNY, *in* EHRENBERG, 1839, K. Preuss. Akad. Wiss. Berlin, Physik. Abh., Jahrg. 1838, table 1, p. 120.

Discorbina PARKER and JONES, *in* CARPENTER, PARKER and JONES, 1862, Ray Soc. Publs., p. 200, 203.

Type Species: *Rotalia* (*Trochuline*) *turbo* d'Orbigny, 1826, Tableau méthodique de la classe des Céphalopodes: Ann. Sci. Nat. Paris ser. 1, v. 7, p. 274.

Test free, trochospiral, plano-convex to unequally biconvex, all chambers visible on the spiral side, only chambers of final whorl visible on umbilical side, with narrow slit opening along the chamber suture extending from the umbilicus to the margin, opening into the chamber cavity; initial chambers of spiral side covered by heavy layer of clear shell material; aperture a slit at the base of the final chamber extending from the margin to the umbilical area, frequently bordered by a thin apertural lip; peripheral margin imperforate with slight thickening or keel; umbilical plug or thickening commonly present; wall radial hyaline, coarsely perforate with bilamellar septa.

Remarks: D'Orbigny (1826) named three species under the French vernacular subgeneric term "Les Trochulines" of which only *Rotalia turbo* was valid. This species name was used in combination with the Latin subgeneric name *Trochulina* d'Orbigny, 1839, by Basset (1885) and therefore becomes the type species of *Trochulina* by subsequent monotypy. *Discorbina* Parker and Jones (1862) also based on *Rotalia turbo* d'Orbigny, 1826, is a junior synonym. In the original description of *Discorbina,* Parker and Jones may have confused *R. turbo* with the type species of *Discorbis,* as both the description and the figure are interlaced with references to the latter. For example,

the authors note "astral flaps" on the preceding chambers in the umbilical region.

Hofker (1951) erected the genus *Discopulvinulina,* within which he included *Rotalia turbo.* The same author later (1954) placed *turbo* in *Rotorbinella* and stated that the species did not occur in the Paris Basin Eocene. Loeblich and Tappan (1964a) noted that several labeled specimens of this species from the Lutetian of the Paris Basin were present in d'Orbigny's collection at the Muséum National d'Histoire Naturelle, Paris, and designated one of them as lectotype. Nevertheless, this species can be readily separated from *Discopulvinulina* by shape and apertural characters and from *Rotorbinella* by wall structure.

Since the citation of the combination *Trochulina turbo* by Basset, apparently no other species have been described under this generic name. Specimens of *turbo* from Mécring and Grignon, France, were sectioned and found to have a bilamellar wall structure (plate 2, fig. 1). For this reason the genus cannot be included with the discorbids, which are monolamellar. On the basis of the information at hand it appears to be a separate and distinct taxon and is herein recognized as such. Examination of numerous species during the preparation of this paper suggests that many of the Tertiary to Recent forms which have previously been referred to *Discorbina, Discorbis* and *Rotalia* are more properly placed in *Trochulina.* However, thin-section analysis of wall structure is necessary for accurate assignment.

Family ROSALINIDAE Reiss, 1963

D. Genus ROSALINA d'Orbigny, 1826

Rosalina D'ORBIGNY, 1826, Tableau méthodique de la classe des céphalopodes: Ann. Sci. Nat. Paris, ser. 1, v. 7, p. 271.

Tretomphalus MÖBIUS, 1880, Beitr. zur Meeresfauna der Insel Mauritius und der Seychellen, p. 67, 99.

Type Species: *Rosalina globularis* d'Orbigny, 1826

Test free or attached, plano- or concavo-convex, trochospiral; aperture interiomarginal and elongate, extending under broad umbilical flap; wall perforate, radial, septa bilamellid; reproductive float chamber developed in some species producing temporary planktonic stage.

Occurrence: Eocene to Recent.

ROSALINA GLOBULARIS d'Orbigny, 1826

Pl. 3, figs. 1-5

Rosalina globularis D'ORBIGNY, 1826, Tableau méthodique de la classe des céphalopodes: Ann. Sci. Nat. Paris, ser. 1, v. 7, p. 271, pl. 13, figs. 1-4.

Rosalina bulloides D'ORBIGNY, 1839, Foraminifères, in Ramon de la Sagra, Histoire physique, politique et naturelle de l'Ile de Cuba, p. 98, pl. III, figs. 2-5.

Discorbis columbiensis CUSHMAN, 1925, Cushman Lab. Foram. Research, Contr., v. 1, p. 43, pl. 6, fig. 13 (a-c).

Discorbis isabelleana (d'Orbigny) (?) CUSHMAN and VALENTINE, 1930, Stanford Univ. Contr. Geology, v. 1, no. 1, p. 23, pl. 6, figs. 6, 7 a-c, 8 a-c.

Tretomphalus bulloides (d'Orbigny) MYERS, 1943, Stanford Univ. ser. Biology, v. 9, no. 1, pl. III, pl. IV, figs. 4-5.

Tretomphalus myersi CUSHMAN, 1943, Cushman Lab. Foram. Research, Contr., v. 19, p. 26-27, pl. 6, fig. 6a-c.

Test free or attached, trochospiral; agamontic individuals benthonic, with planoconvex test, all chambers visible from convex spiral side, only those of final whorl visible on flattened umbilical side; chambers are distinct and range from 18-21 in number, with 5-6 in the final whorl, later chambers commonly irregular, periphery moderately lobate to angled; sutures radial, curved, slightly depressed; wall thin, calcareous, bilamellid, perforate, with few large pores in early chambers replaced by smaller and more numerous ones in later chambers, central periphery and umbilical flaps commonly imperforate; aperture interiomarginal, umbilical and elongate, extending from near the periphery to the umbilicus, where its posterior extension continues under the broad umbilical flap for about one-third the distance along the previous suture; gamontic individuals benthonic in early stages, planktonic in later stages with a more high spired test, plano- or concavo-convex, umbilical side flat to concave (pl. 3, fig. 1a-c); chambers more inflated, ranging from 10-16, with 5-6 in the final whorl; sutures radial, curved; during gamogony a nearly hemispherical float chamber develops over umbilical region (pl. 3, fig. 4a-b) enclosing a spherical, thin walled gas float with internal tube (pl. 3, fig. 2), allowing test to assume a temporary planktonic habit, biflagellate gametes develop within the chambers and the area between the float and float chamber, escape through the areal float chamber pores to fuse and produce agamontic generation; aperture as in agamont but commonly depressed in concave umbilical surface.

Remarks: The genus *Rosalina* was described by d'Orbigny (1826) but without designation of a type species. Galloway and

Wissler (1927) redescribed the genus and fixed *R. globularis* as the type. D'Orbigny regarded the species as widespread, as he gave the occurrence merely as "all the seashores of the ocean", adding that it is attached to algae and polyps. These remarks appear well founded as the writers have examined specimens from Queen Charlotte Sound, British Columbia, Santa Monica Bay, California, and Punta Baja, Mexico, and from Florida, Cuba and the Antarctic. Such a world wide geographic distribution suggests that the numerous presently recorded "species" of *Rosalina* and related genera should be carefully restudied. Furthermore, additional occurrences should be carefully compared to existing species before proposal of additional names.

Laboratory studies by Sliter (Jour. Protozool., in press) on the life cycle of *R. globularis* disclosed the development of the float-chambered planktonic stage that is identical to the holotype of *Tretomphalus myersi* Cushman. Specimens of this float-chambered stage were also compared to a topotype of *T. bulloides* (d'Orbigny) (=*R. bulloides* d'Orbigny) and again found to be identical. Thus *T. myersi* is a junior synonym of *T. bulloides,* and because *R. bulloides* d'Orbigny is the type species of *Tretomphalus* Möbius, the latter becomes a junior isotypic synonym of *Rosalina.*

The rejection of the genus *Tretomphalus* leaves certain other species without generic assignment until life cycle studies can make it possible definitely to place them in their correct taxonomic position. It has been noted (Cushman, 1934) that the initial chambers of the various species referred to *Tretomphalus* are decidedly different, with only the final float chamber common to all. On the basis of morphologic characters the following recommendations are presently proposed for the placement of species previously referred to *Tretomphalus.*

The species characterized by a rosalinid early stage are here referred to *Rosalina* and probably represent only the reproductive stage of other rosalinid species. These include the species *R. clarus* (Cushman), and *R. concinnus* (Brady). The remaining species possess the morphologic features of *Cymbaloporetta.* Here included are those with 1) early chambers trochospiral, later chambers added in an alternating annular series, 2) sutures deeply depressed and radial on umbilical side with small, central umbilicus and, 3) apertures consisting of umbilical, sutural openings bordering chambers. The final chamber is again a globular, float chamber. The following species are here referred to *Cymbaloporetta: C. atlanticus* (Cushman), *C. pacificus* (Cushman), *C. milletti* (Heron-Allen and Earland), *C. grandis* (Cushman), and *C. planus* (Cushman).

The variable morphologic characters of rosalinids, due to their attachment during various stages of growth (fig. 2, a-f) has been noted by several authors (Myers, 1943; Cushman and Todd, 1947; Cooper, 1961; Reiss, 1963; Uchio, 1960). *Rosalina globularis* is no exception, and varies considerably in test height and shape, chamber shape, suture curvature and thickness, number of pores in the initial chambers, float-chamber shape and float pore size and arrangement. Examination of the holotype of *Discorbis columbiensis* Cushman, (pl. 3, fig. 3a-c) to which most of the American West Coast examples of *Rosalina* have been assigned, demonstrates that it falls within the range of variation of *R. globularis* (see fig. 2). Also conspecific with this species is *Discorbis monicana* Zalesny, including the paratypes in part. The plesiotype of *D. isabelleana* (d'Orbigny) (?) Cushman and Valentine was examined and adjudged to be a phenotypic variant of *Rosalina globularis,* closely resembling a specimen taken from coralline algae (fig. 2d). The holotypes of *D. mira* Cushman, *D. floridana* Cushman and *D. subbertheloti* Cushman were found to differ from *R. globularis* although their original illustrations closely resemble this species. *D. subbertheloti* is considered to be a rosalinid based on the open umbilicus and lack of pronounced chamber flaps characteristic of *Discorbis.* But it differs from *R. globularis* in being finely perforate and moderately keeled. *D. mira* possesses the same rosalinid feature with the umbilicus nearly obscured by umbilical flaps. This species also differs from *R. globularis,* in the hyaline wall, sharply angled periphery and scarcity of pores. On the basis of test morphology and mode of reproduction *D. floridana* is neither a discorbid nor rosalinid. Without additional material to section for wall character determination, its present taxonomic placement must remain tentative. The species certainly bears a more than superfical

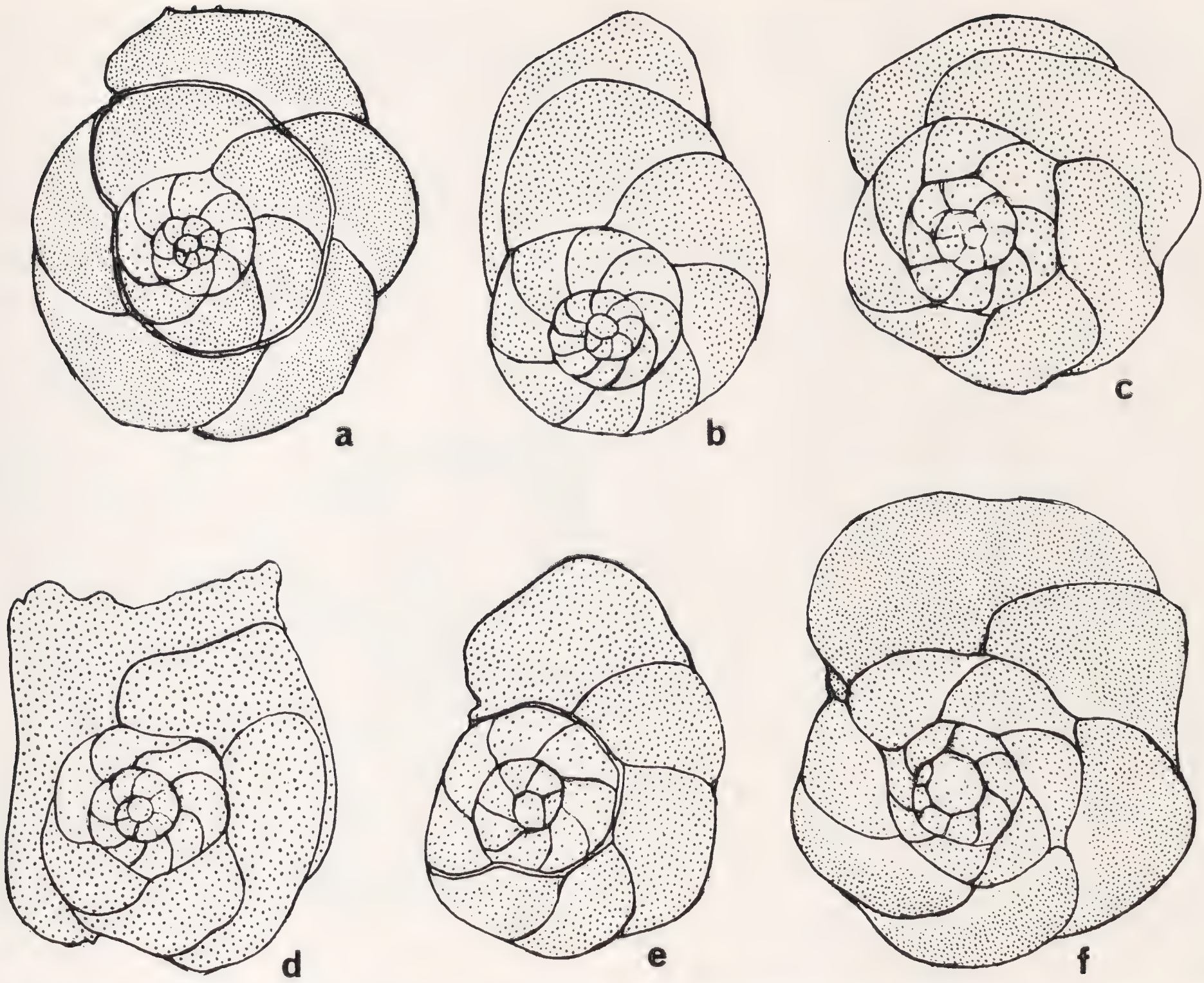

Figure 2. Spiral view of agamontic specimens of *Rosalina globularis* illustrating possible degree of phenotypic variation. a, X72; b and d, X134; c, e, and f, X99. (All figures camera lucida drawings, prepared by Mrs. Martha Matthews).

morphologic resemblance to *Glabratella,* in the lobate periphery and open, pustulose umbilicus. However, this species has an interiomarginal aperture rather than the umbilical aperture of *Glabratella* and it lacks the characteristic umbilical radial ornamentation. The degree of such ornamentation may vary considerably, being absent or nearly so in some specimens (Helen Tappan Loeblich, personal comm.). Species showing the interiomarginal aperture have been noted previously (Bermudéz, 1952) and are now placed in *Angulodiscorbis* (Loeblich and Tappan, 1964a). Such assignment is not applicable for *D. floridana* as this species does not have the high spired test required by the generic definition. Life cycle studies of *D. floridana* (Lee, *et al.,* 1963) indicate that the foraminifer undergoes a plastogamic mode of reproduction. This evidence further suggests a placement with the glabratellids, although Lee *et al.* placed it in *Rosalina.* An additional reference has been made to plastogamy in *Rosalina* (Todd and Low, 1961) but their pleisotypes of *R. globosa* (Sidebottom) were examined and found to belong to *Glabratella.* On the basis of morphology and the reported plastogamic type of reproduction *D. floridana* is here tentatively placed in *Glabratella.*

A plastogamic mode of reproduction has never been observed during laboratory experiments with cultures of *Rosalina globularis* (Myers, 1943; Sliter, in press). In this species reproduction is limited to 1) the pelagic stage modification of the alteration of generations, and 2) the common apogamic reproduction (asexual production of successive agamontic stages). Presently plastogamy is known only in the Glabratellidae, Spirillinacea and Ceratobulimindae (Loeblich and Tappan, 1964a). Other species that are found to undergo plastogamy should be carefully examined before inclusion in genera of other families.

In wall character both generations of *R.*

globularis are calcareous, perforate, radial in structure and bilamellid as noted by Reiss (1963) (see pl. 2, fig. 2). For the latter reason, the genus *Rosalina* can no longer be included in the Discorbidae Ehrenberg (Loeblich and Tappan, 1964a). The writers therefore agree with Reiss (1963) and Loeblich and Tappan, (1964b) in the recognition of the family Rosalinidae for this common and widespread group of organisms.

VI. Conclusions

Based on life cycle studies, wall structure, and comparison with type material, the following taxonomic revisions are made.

Topotype material of *Discorbis vesicularis* Lamarck was sectioned and shown to be monolamellar. The genus *Rotorbinella* Bandy (synonyms *Biapertorbis* Pokorný and *Gavelinopsis* Hofker) is also monolamellar, and retained within the subfamily Discorbinae, but its distinct morphologic characters (*i.e.,* apical thickening, solid central column, and higher spire, etc.) are of generic value, hence it is regarded as distinct and not a synonym of *Discorbis.*

Trochulina d'Orbigny (synonym, *Discorbina* Parker and Jones) is recognized as a distinct bilamellar genus, removed from the subfamily Discorbinae, and placed in the family Eponididae, superfamily Orbitoidacea. The following taxa are regarded as conspecific and referred to *Rotorbinella campanulata* (Galloway and Wissler): *Globorotalia campanulata* Galloway and Wissler, *Rotalia turbinata* Cushman and Valentine, *Rotalia lomaensis* Bandy, and *R. versiformis* Bandy, *Rosalina campanulata* (Galloway and Wissler) Uchio, *Rotalia* spp. Walton and *R. avalonensis* Natland.

Tretomphalus Möbius is a junior synonym of *Rosalina* d'Orbigny as the type species of the former is conspecific with the type species of *Rosalina.* Specific synonyms of *R. globularis* are: *Discorbis columbiensis* Cushman, *D. monicana* Zalesny, *Tretomphalus myersi* Cushman and *D. isabelleana* (d'Orbigny) (?) Cushman and Valentine. *Discorbis mira* Cushman and *D. subbertheloti* Cushman belong to the genus *Rosalina* but appear to be distinct species. Because of its morphology and mode of reproduction *D. floridana* is considered to be a glabratellid. Reproduction of *R. globularis* involves a sexual pelagic stage and an asexual benthonic phase; plastogamy is unknown in the family Rosalinidae Reiss. *R. globularis* is shown to be bilamellar and the family Rosalinidae is therefore placed in Orbitoidacea Schwager.

Glaessner (1963) criticized the primary use of septal layering as a satisfactory basis for major classification. Laboratory experiments on living foraminifers undertaken to date, however, suggests that wall structure is a genetic character unaffected by ecologic-environmental controls. The writers have collected and cultured species from lagoonal, intertidal, nearshore, and continental shelf environments up to 300 feet deep. Species from each of these ecologic realms have been cultured in the laboratory for as long as two years, under approximate natural conditions to extreme conditions far exceeding those of the natural habitat. Effects on different species of Foraminiferida produced by varying such factors as food, light, salinity, temperature, and pressure have been and are presently being studied. During these studies examples have never been found to change the basic test structure, such as type of wall septa lamellae, wall structure, and others. The ecologic factors enumerated above may produce a certain amount of phenotypic variation. This morphologic variation is minor, and the fundamental test characteristics are easily recognized. Morphologic variation brought about by the

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Plate 1

Figures Page

1. *Discorbis vesicularis* Lamarck 151

Lutetian, Grignon, Paris Basin, France. 1a, horizontal section of topotype showing monolamellar septa; 1b, axial section of topotype, both X 100.

2. *Rotorbinella campanulata* (Galloway and Wissler) 153

Recent. 2a, axial section showing central axial column, X 130; 2b, horizontal section showing monolamellar septa, X 125.

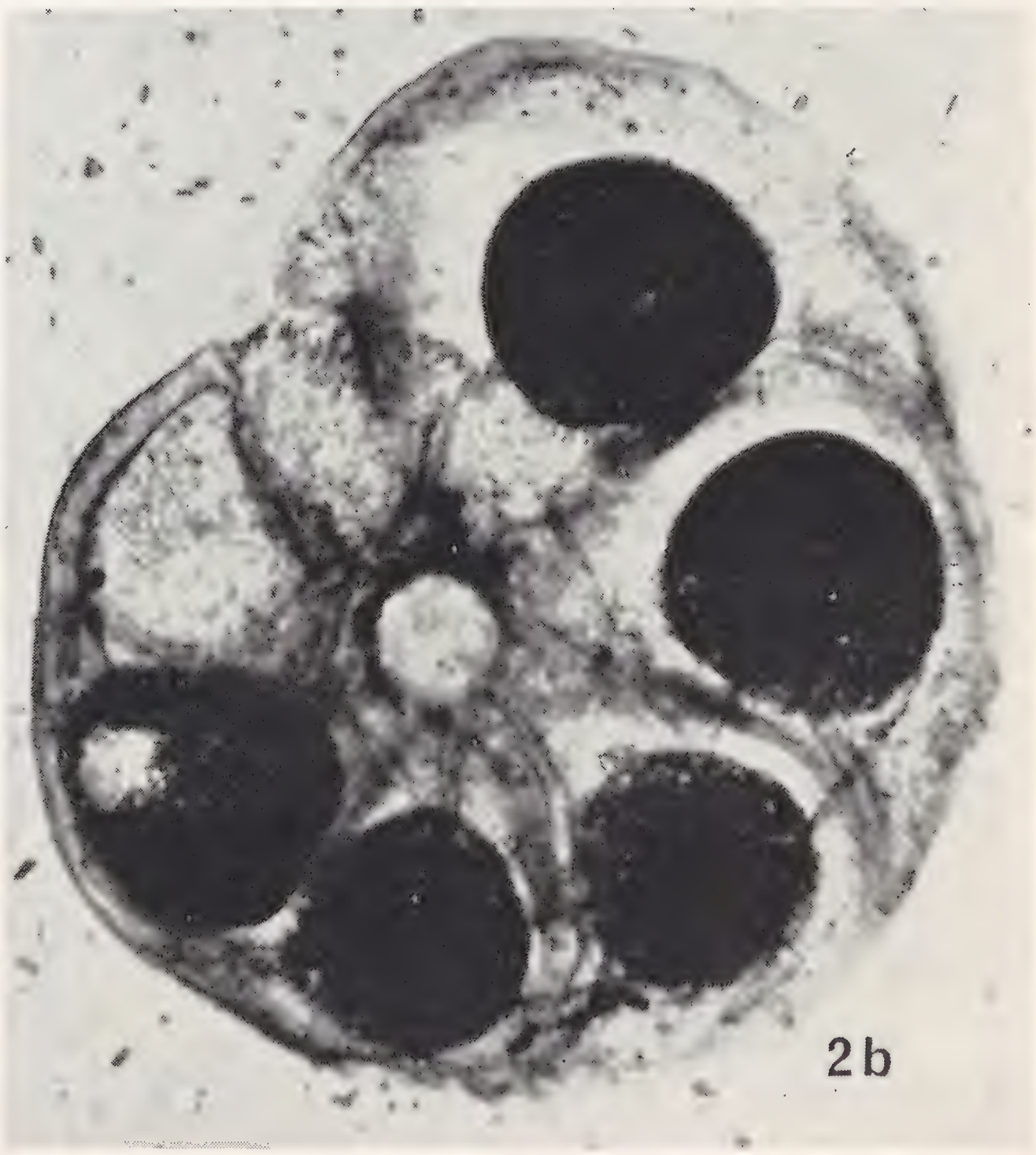

PLATE 1

different reproductive methods in the life cycle of a species may appear to approach generic level (Sliter, in press). In all cases examined by us, however, the characteristic test structure has remained unchanged regardless of reproductive generation. If a single morphologic character can provide a basis for foraminiferal classification, then wall structure would appear to provide the best criterion.

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Plate 2

Figures Page

1. *Trochulina turbo* d'Orbigny 154

   Lutetian, Grignon, Paris Basin, France. 1a, enlarged view of portion of section in 1c, showing bilamellid septa, X 180; 1b, axial section of topotype, X 62; 1c, horizontal section of topotype showing bilamellid septa, X 62.

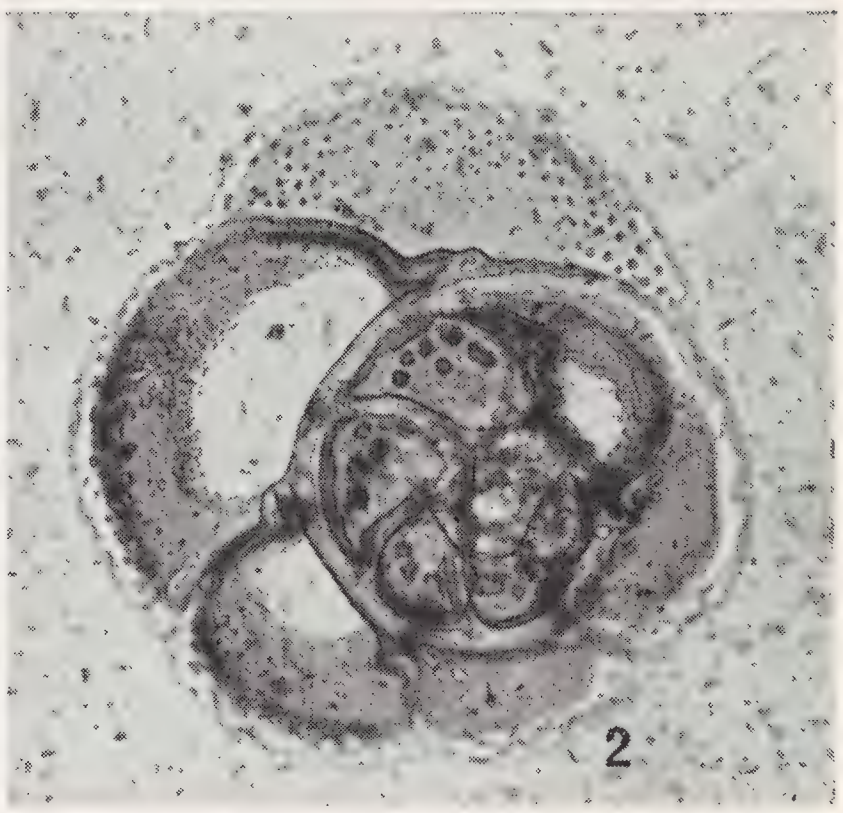
2. *Rosalina globularis* d'Orbigny 155

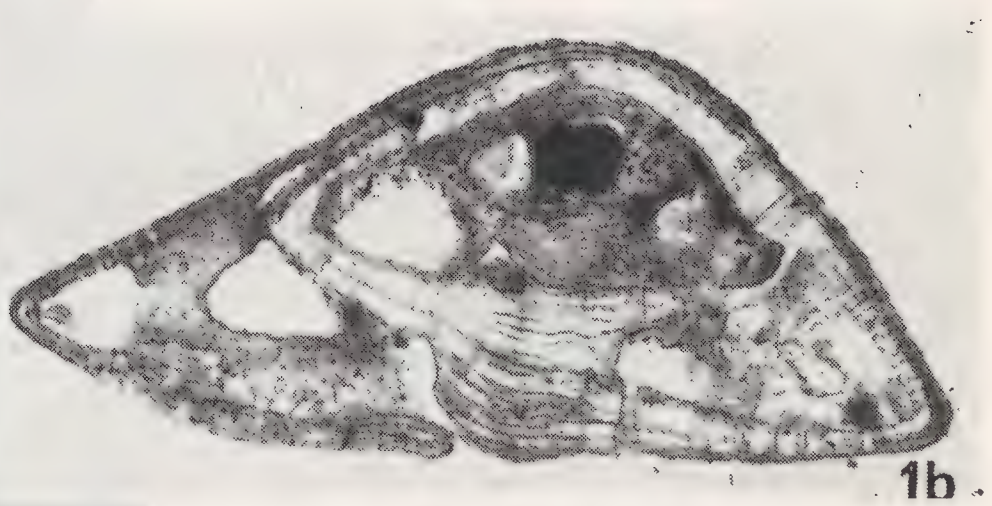
   Recent. Horizontal section showing bilamellar septa, X 130.

3. *Rotorbinella praegeri* (Heron-Allen and Earland) 153

   Recent, Sahul Shelf, N. W. Australia. Horizontal section of hypotype, showing monolamellar septa, X 130.

(All figures are unretouched photographs.)





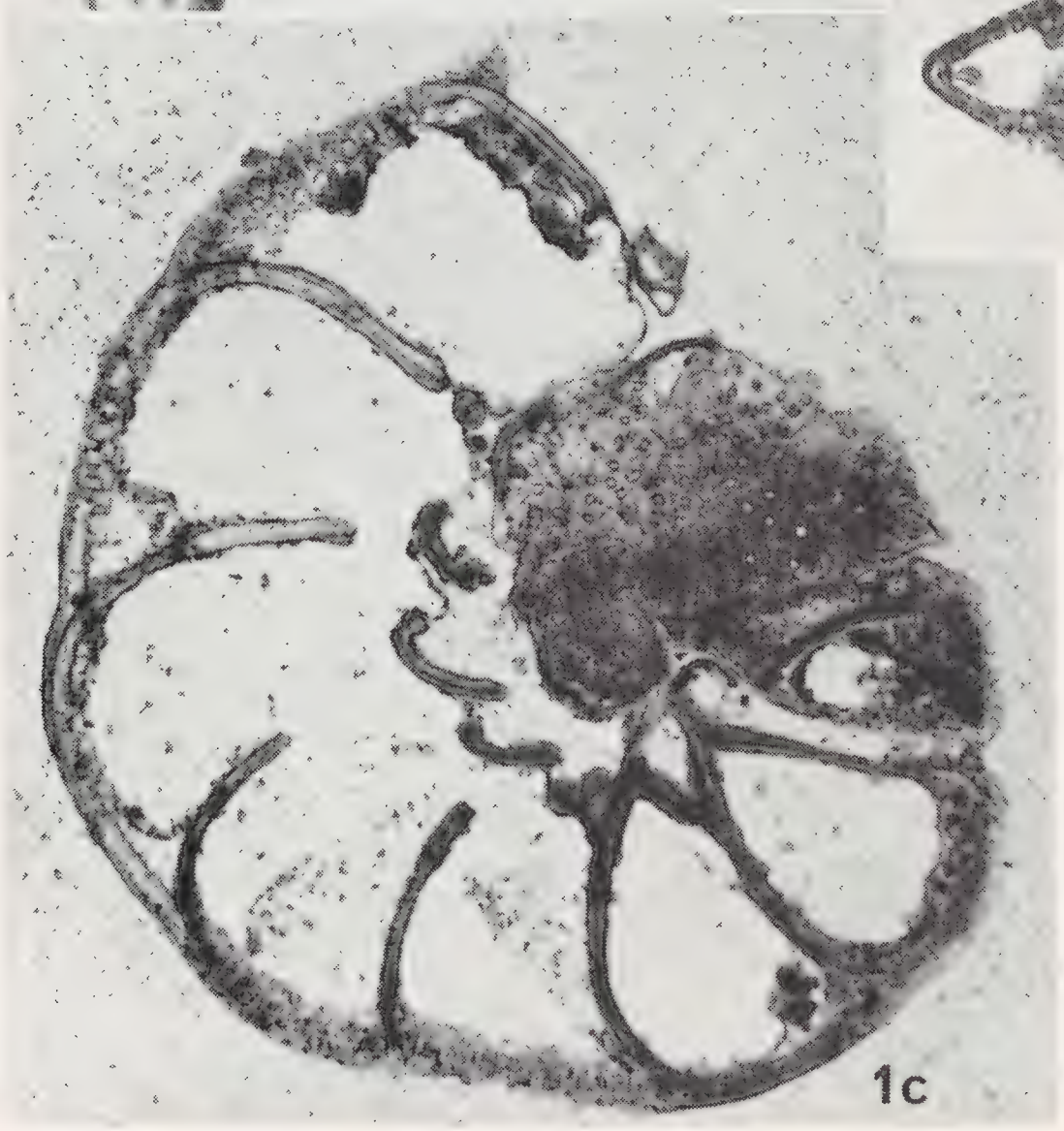


PLATE 2

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PLATE 3

Figures Page

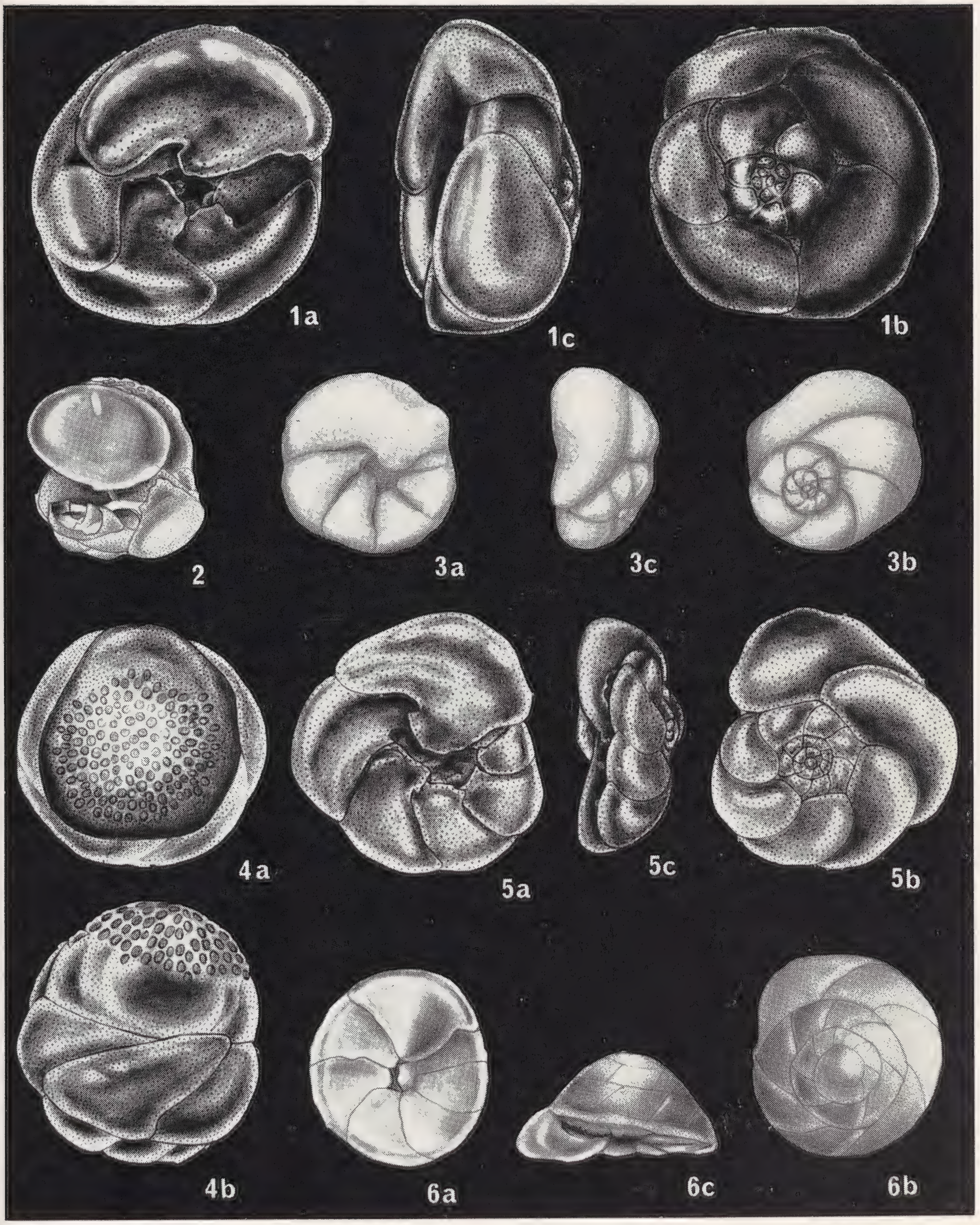
1-5. *Rosalina globularis* d'Orbigny 155

Recent. 1a-c, umbilical, spiral and peripheral views respectively of gamont without float chamber, X 130; 2, peripheral view of etched gamont with float chamber wall removed to show interior gas float and tube, X 66; 3a-c, umbilical, spiral and edge views of holotype of *Discorbis columbiensis* Cushman, redrawn X 88; 4a-b, areal and peripheral views of *R. globularis* with float chamber, X 88; 5a-c, umbilical, peripheral and spiral views of agamont, X 88.

6. *Rotorbinella campanulata* (Galloway and Wissler) 153

Pleistocene. 6a-c, umbilical, peripheral, and spiral views of topotype, Lomita Marl, X 66.

(All figures are shaded camera lucida drawings: Figs. 1a-c, 2, 4a, b, 5a-c, 6a-c, by Mrs. Martha Matthews, Fig. 3a-c by Helen Tappan Loeblich.)



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PHOTOMETRIC DETERMINATION OF PREFERRED ORIENTATION OF FELDSPARS IN FINE-GRAINED IGNEOUS ROCKS

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CONTENTS

Page

I. ABSTRACT 165
II. INTRODUCTION 165
III. PHOTOMETRIC TECHNIQUE 166
IV. DISCUSSION OF RESULTS 167
V. DEGREE OF ORIENTATION 171
VI. CONCLUSIONS 171
VII. ACKNOWLEDGMENTS 172
VIII. LITERATURE CITED 172
TABLE I: Degree of Orientation Expressed in Percent 171
PLATE 1: Equipment 173
PLATE 2: Photomicrographs 174

I. ABSTRACT

The crystal habit and optical orientation of many feldspars combine to provide a convenient means for determining shape orientation from optical data. Results from photometric determinations of five different units show that it is possible to deduce, within narrow limits, major flow patterns producing planar orientation in certain fine-grained igneous rocks. It may be possible to determine the direction of flow from such a technique.

II. INTRODUCTION

Feldspars are commonly tabular enabling them to align with the flow in a fluid magma. The optical orientation, being fixed for a given composition, reflects this alignment and may be detected by the procedure described in this paper. Balk (1937, p. 14) has indicated the tendency of feldspar phenocrysts to show a platy parallelism. Also, Waters (1960, p. 365) has reported a parallelism of the (010) plane of microphenocrysts of plagioclase with the base of some flows of Columbia River basalt in the zone near the base. In an igneous rock, therefore, in which there is preferred orientation of the tabular feldspars they appear optically in agreement when viewed parallel to the direction of planar orientation.

A strong preferred orientation of such grains in thin section can be detected by eye under crossed nicols with the aid of the gypsum plate. A weak orientation may be detected by a photometer technique, which has been used for studying quartz fabrics (Martinez, 1958). This method involves

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measuring by means of a photometer the variation in the intensity of light with a wave length dominantly of 750 millimicrons passed through a standard thin section on the stage of a petrographic microscope with a gypsum plate inserted and nicols crossed during a 360° rotation of the stage. Maximum intensity of light occurs when the trend of the directions of vibration of the fast rays lies parallel with the slow direction of vibration of light in the gypsum plate.

The method described here functions for albite, oligoclase, andesine and labradorite. Z is not normal to (010) but is more nearly so than parallel with it in these plagioclases (Emmons, 1943, figs. 53-56; Muir, 1955, figs. 1, 2). It follows that the average relation of Z to (010) for a number of grains rotated about *b* will be Z normal to (010). Albite twinning in the plagioclases should not affect this statistical relationship. Crystals of plagioclase tabular parallel to (010), a common habit (Winchell, 1951, p. 312), should appear statistically length-fast when viewed from any direction normal to *b*. Thus, preferentially oriented tabular plagioclases in a section of an igneous rock should be length-fast, when viewed parallel to a planar orientation.

According to Winchell (1951, pp. 265, 312) plagioclase crystals are also sometimes elongated parallel to *a* and feldspar microlites are usually of this habit, except that when larger, they may be tabular parallel to (010). Other habits listed by Winchell are elongation parallel to *b* and, rarely, elongation parallel to *c*. Brinkman (1957) in discussing mineral orientation in basalts, stated that the plagioclase laths were elongate parallel to *c*.

The optical orientations shown by Muir (1955, figs. 1, 2) suggest that plagioclase crystals as calcic as about An_{50} and elongated parallel to *a* favor a length-fast aggregate orientation when viewed in any direction normal to *a*. Plagioclase crystals more calcic than An_{50} should average out to be length-fast if elongated parallel to *c* when viewed in any direction normal to *c*. Laths of highly calcic plagioclase elongated parallel to *a* and the more sodic plagioclases elongated parallel to *c* may appear statistically length-slow when viewed in a direction normal to a planar orientation containing a lineation. Plagioclase less calcic than An_{70}, elongated parallel to *b*, should be statistically length-slow viewed normal to *b*. *Tabular* plagioclase less calcic than An_{70}, however, would be statistically length-fast when viewed parallel to a planar orientation and also for a considerable range diverging from this direction if not for most directions.[1] The length-fast length-slow relations for other habits discussed above also hold true for quite a range of directions and for probably a greater range of compositions than those indicated as limits.

III. Photometric Technique

Comparison of trends of fast-ray vibration directions obtained from photometric measurements with long-axis determinations of feldspar laths have been made for a number of fine-grained igneous rocks. The photometric technique employed was essentially that described by Martinez (1958) except that the output of the photocell was measured directly by an ohmmeter. Figure 3, Plate 1 shows the equipment employed. The photocell (Clairex Corporation number CL503AL), shown in Figure 2, Plate 1, peaks at 733 millimicrons. It is shown mounted in Figure 1, Plate 1. It was adapted to fit over the vertical tube of an L2300TP-QR American Optical polarstar trinocular petrographic microscope. The image was focused on the sensitive element of the photocell by a 5X eyepiece placed in the vertical tube. The two positions of the stage for both minimum and maximum light intensity were recorded. Because an ohmmeter was used directly rather than using a galvanometer in a more sensitive circuit some imprecision resulted in these determinations. The limits of error were minimized by averaging the data. The two positions for minimum intensity were equally adjusted to differ by 180 degrees. The same adjustment was made for the positions of maximum intensity. If these adjusted positions of maximum and minimum intensity did not differ from each other by 90 degrees they were equally adjusted to so differ. The position of maximum intensity thus determined is considered to represent that position at which the trend of the directions of vibration of the fast rays is parallel or very nearly parallel with the slow direction of vibration of light in the gypsum plate. No

[1] This generalization is supported by the empirical data given in section IV.

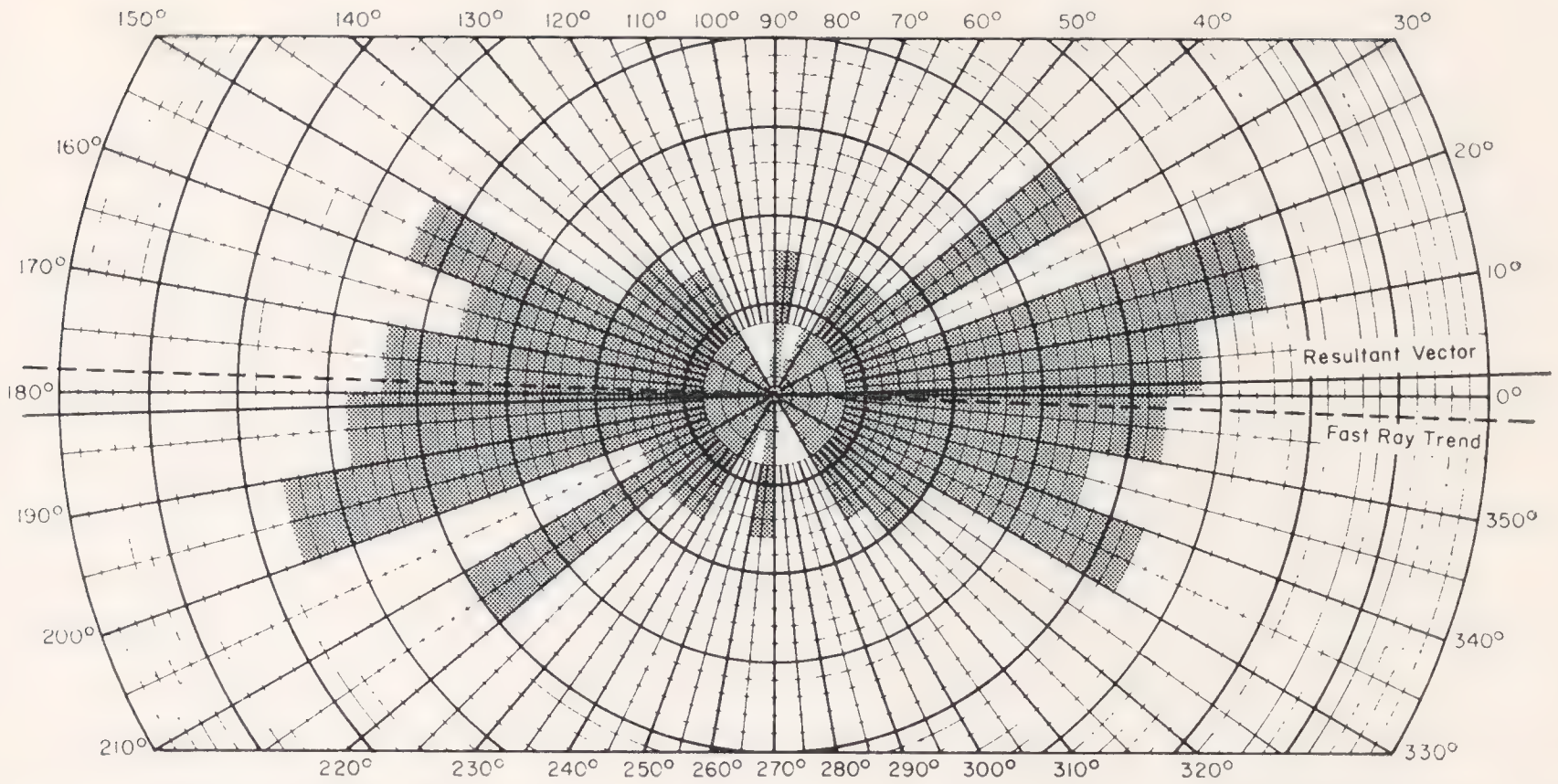

Figure 1. Comparison of the fast ray trend with 101 long axis determinations of feldspar laths longer than .057 mm in section CH577A-2 of a basalt from the Big Bend National Park.

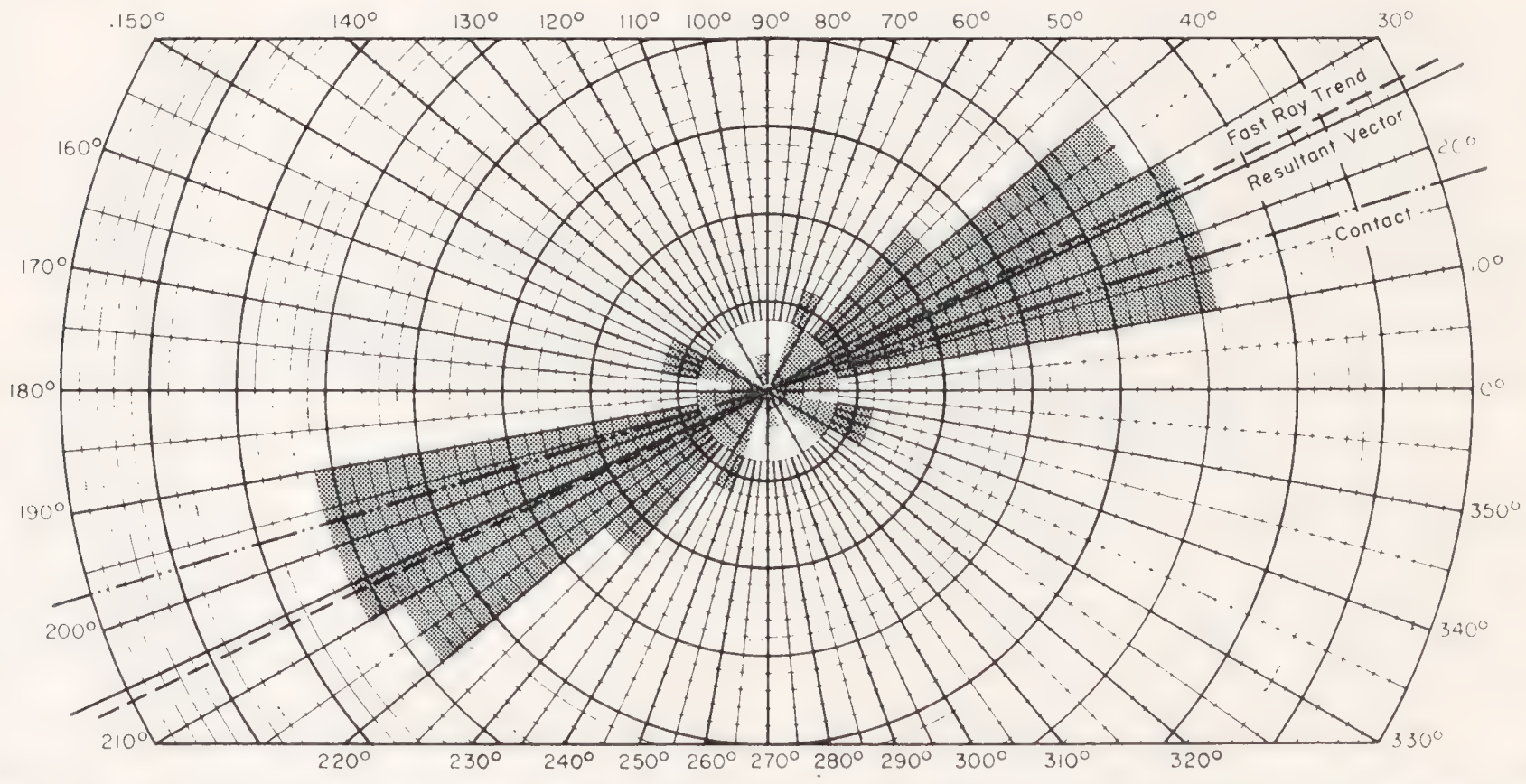

Figure 2. Comparison of the fast ray trend with 68 long axis determinations of feldspar phenocrysts in a thin section from the Higganum dike.

attempt was made in this work to correct for possible errors due to directional effects of the photocell. Three to six 9.5 mm square areas of each section were measured. The direction of preferred orientation in each section was obtained by using a vector method for averaging the individual measurements made for each section (Curray, 1956, p. 118-120). For these computations, each individual observation was considered to be of the same magnitude.

IV. Discussion of Results

A thin section of the Ash Spring basalt from the Big Bend National Park (Lonsdale, *et al.,* 1955) was used for a comparison. This rock is fine grained, composed predominantly of oligoclase laths in an intergranular texture. Figure 1 is a polar histogram showing the results of 101 long axis determinations of feldspar laths longer than .057 mm in an unoriented section of this basalt. These data were plotted in 10° class intervals. To obtain a resultant vector for this distribution, a procedure similar to that described by Curray (1956, p. 118-120) was employed. Each 10° class interval was considered to represent an observation vector passing through the center of the class interval and having the magnitude of the class interval. The angles of these observation vectors from the zero position on the plot were doubled and a vector average was determined graphically. The angle thus

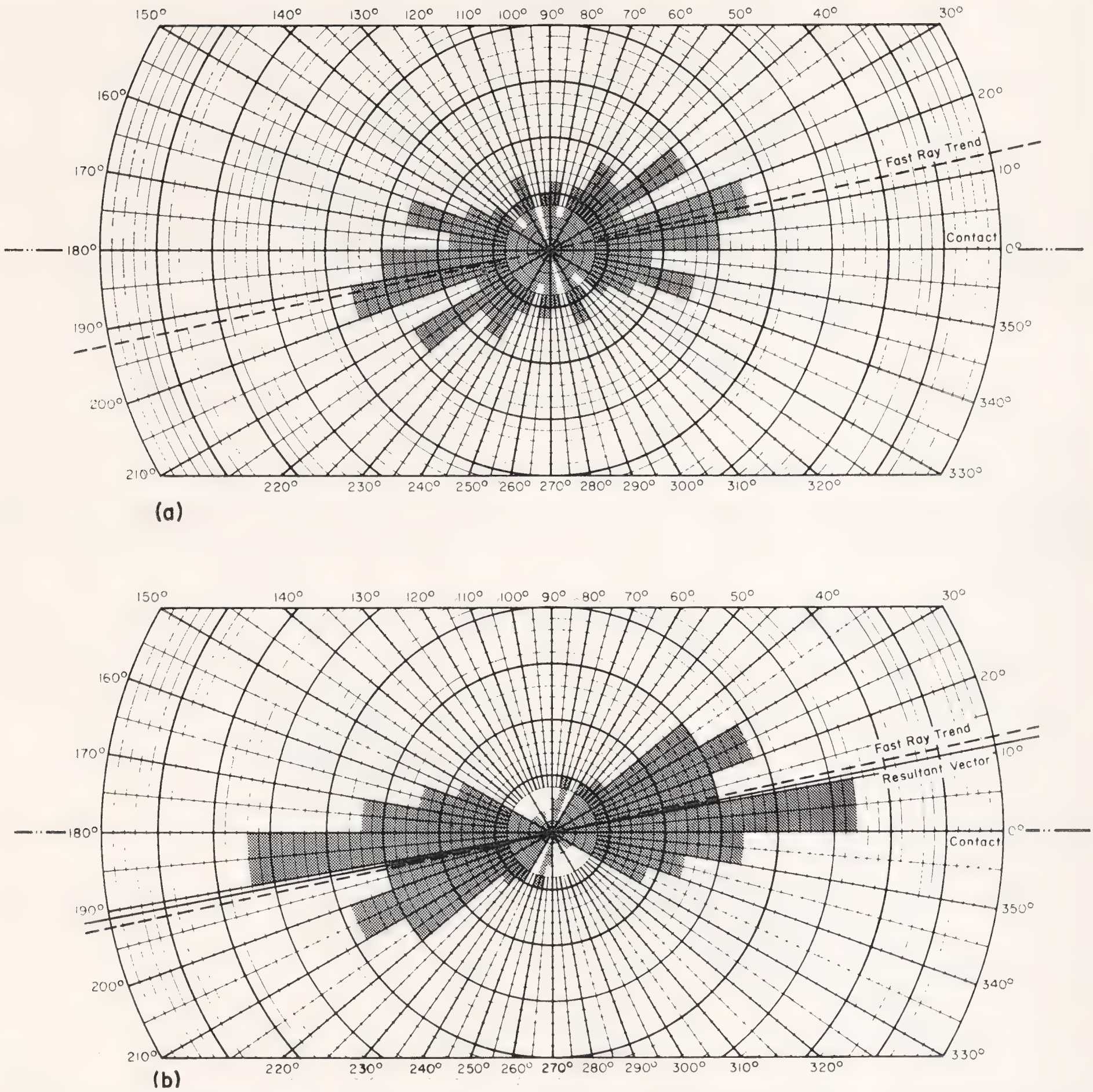

Figure 3. Comparisons of the fast ray trend with 143 long axis determinations of feldspar laths longer than .057 mm in section 36 of the Bridgeport dike. (a) long axis determinations along traverses parallel to contact; (b) long axis determinations along traverses normal to contact.

obtained was divided by two to get the resultant vector direction. The resultant vector magnitude, expressed in percent, is obtained by dividing the vector sum by the total number of measurements. The resultant vectors shown on other figures in this paper were computed in the same manner. This computed resultant vector lies only 4° from the fast-ray trend of the feldspars which was determined photometrically. The long-axis determinations were obtained along traverses normal to the 0°-180° line on Figure 1. This has the effect of enhancing the apparent preferential orientation but should not introduce too large an error in the computed direction. Traverses at right angles to this direction would have the opposite effect of attenuating the true preferential orientation. For some of the other sections described, I have made determinations in both ways. The photometric technique overcomes to some extent this real dilemma in measuring trends of such elongate grains.

Figure 2 gives a comparison of the photometrically determined fast-dry trend with 68 long-axis determinations of labradorite phenocrysts in a thin-section of a basalt dike in Higganum, Connecticut. Figure 3, Plate 2, is a photomicrograph of this section. The diameter of the field is approximately 5.5 mm. This section is porphyritic and holocrystalline. Feldspar phenocrysts range from

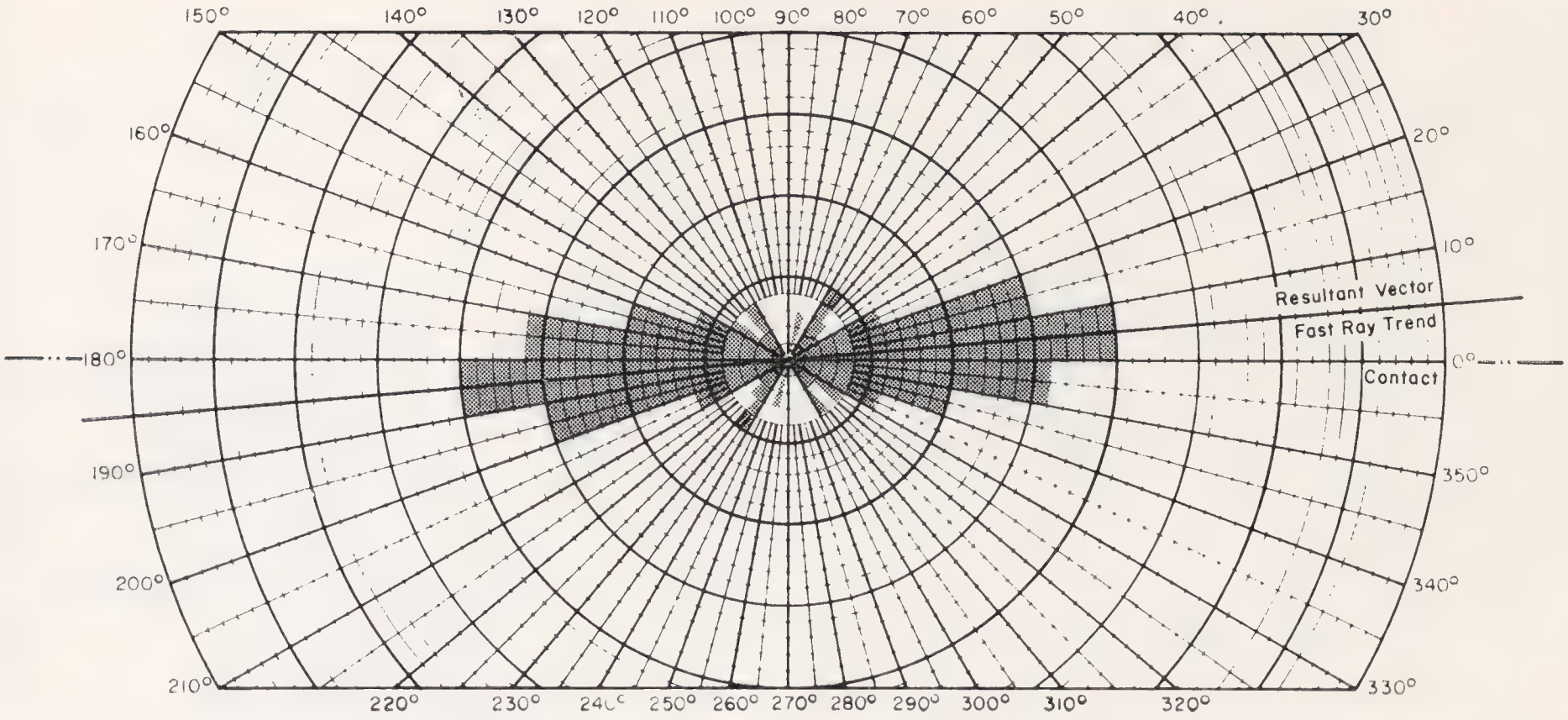

Figure 4. Comparison of the fast ray trend with 99 long axis determinations of feldspar laths longer than 0.3 mm in section 35 of the Bridgeport dike. The determinations were made along traverses normal to the contact.

slightly over 0.1 mm to nearly 2 mm in length. The groundmass consists of pyroxene and feldspar grains approximately .02 mm in diameter. Visual examination under crossed nicols with the gypsum plate inserted shows the optical orientation of the phenocrysts and the plagioclase crystals in the matrix to be almost identical. The contact of the dike and the country rock is included in the section. The fast-ray trend differs from the resultant vector of long axis determinations by only 1 degree. Both trends approach parallelism with the contact, but there is an appreciable angular difference. This may be of genetic significance.

Comparisons have been made in two mutually perpendicular sections cut adjacent and normal to the contact of a basalt dike in Bridgeport, Connecticut. The groundmass ranges from cryptocrystalline at the contact to very finely crystalline at the other side of the section. Phenocrysts include labradorite, clinopyroxene, and altered olivine, ranging from less than .1 mm to as much as 1.3 mm in their maximum dimension. Figure 3a shows a comparison of the inferred photometrically determined fast-ray trend with 143 long-axis determinations of feldspar laths longer than .057 mm in section 36. These long-axis determinations were made along traverses parallel to the contact. Figure 3b is similar to 3a except that the traverses were normal to the contact. The fast-ray trend differs from the resultant vector by only 2 degrees. Figure 4 gives a comparison of the inferred (010) trend with 99 long axis determinations of feldspar laths longer than 0.3 mm in section 35. These determinations were made along traverses normal to the contact. In this section the fast-ray trend is coincident with the resultant vector. As in the section of the Higganum dike, the fast-ray trend and the resultant vector were not exactly parallel with the contact.

Figures 5a thru 5c show results obtained from a vertical thin-section of the Hampden basalt on the campus of Trinity College in Hartford, Connecticut from about 6 inches above the base of this Triassic lava flow. This sample of the basalt is fine-grained with a porphyritic and intersertal texture. Most of the groundmass feldspars range in length from about 0.1 mm to 0.2 mm. The phenocrysts range from about 0.3 to nearly 2.0 mm. The plagioclase is andesine which shows sericitization and partial replacement by calcite. Figure 5a gives a comparison of the fast-ray trend with 139 long-axis determinations along vertical traverses of laths longer than 0.32 mm. In this instance the fast-ray trend differs from the resultant vector by 10 degrees. The apparent dip of the flow in this plane is also indicated on the plot. Figure 5b is a plot showing the comparison of the fast-ray trend with 188 long-axis determinations along traverses normal to the horizontal of laths longer than .057 mm. Results are similar to 5c. The fast-ray trend differs by 8 degrees from the resultant vector. Figure 5c represents a comparison of the fast-ray trend with 257 long-axis deter-

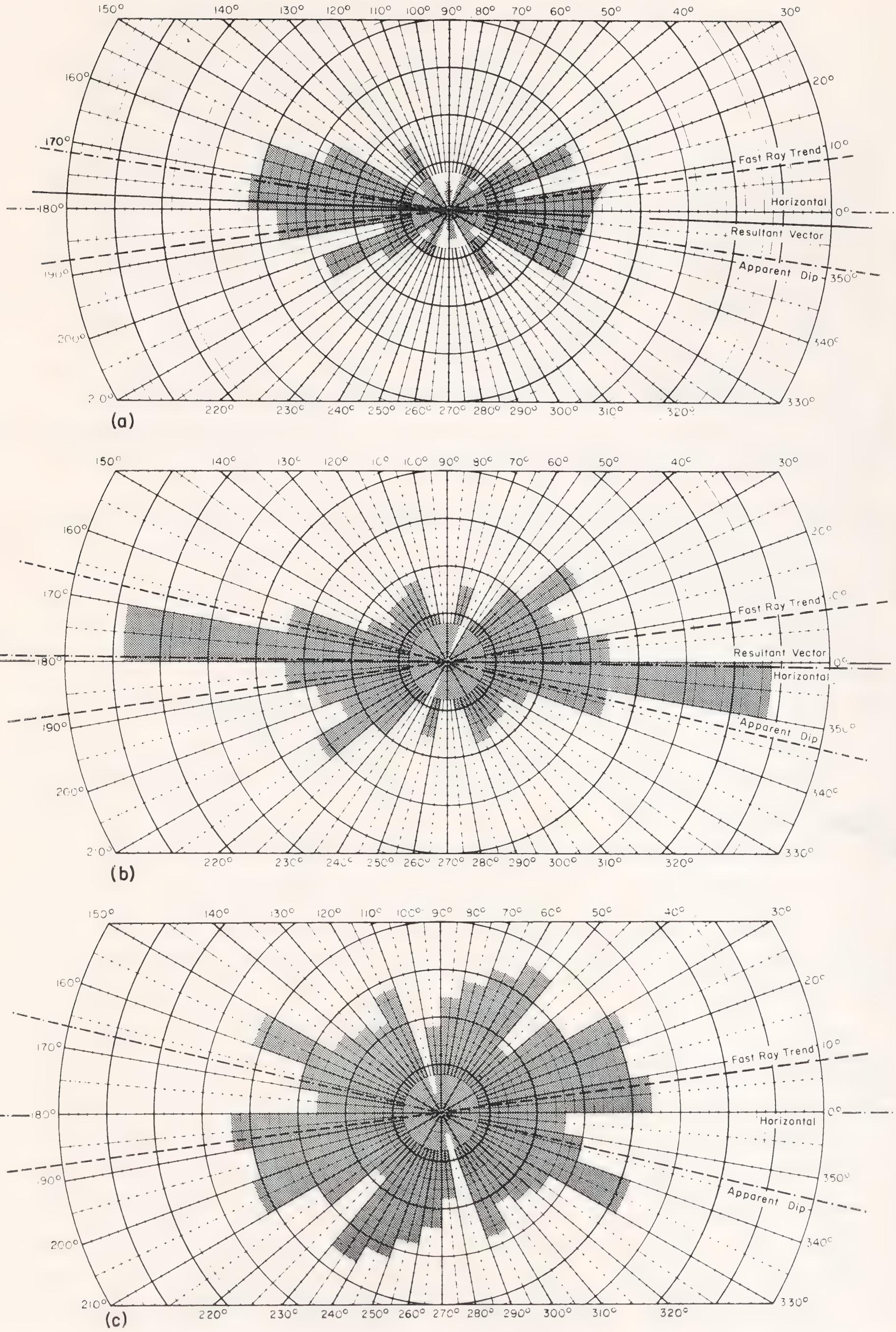

Figure 5. Comparison of the fast ray trend with long axis determinations of feldspar laths in section 40 (vertical) of the Hampden basalt. (a) 139 determinations along traverses normal to the horizontal of laths longer than 0.32 mm; (b) 188 determinations along traverses normal to the horizontal of laths longer than .057 mm; (c) 257 determinations along traverses parallel to the horizontal plane of laths longer than .057 mm.

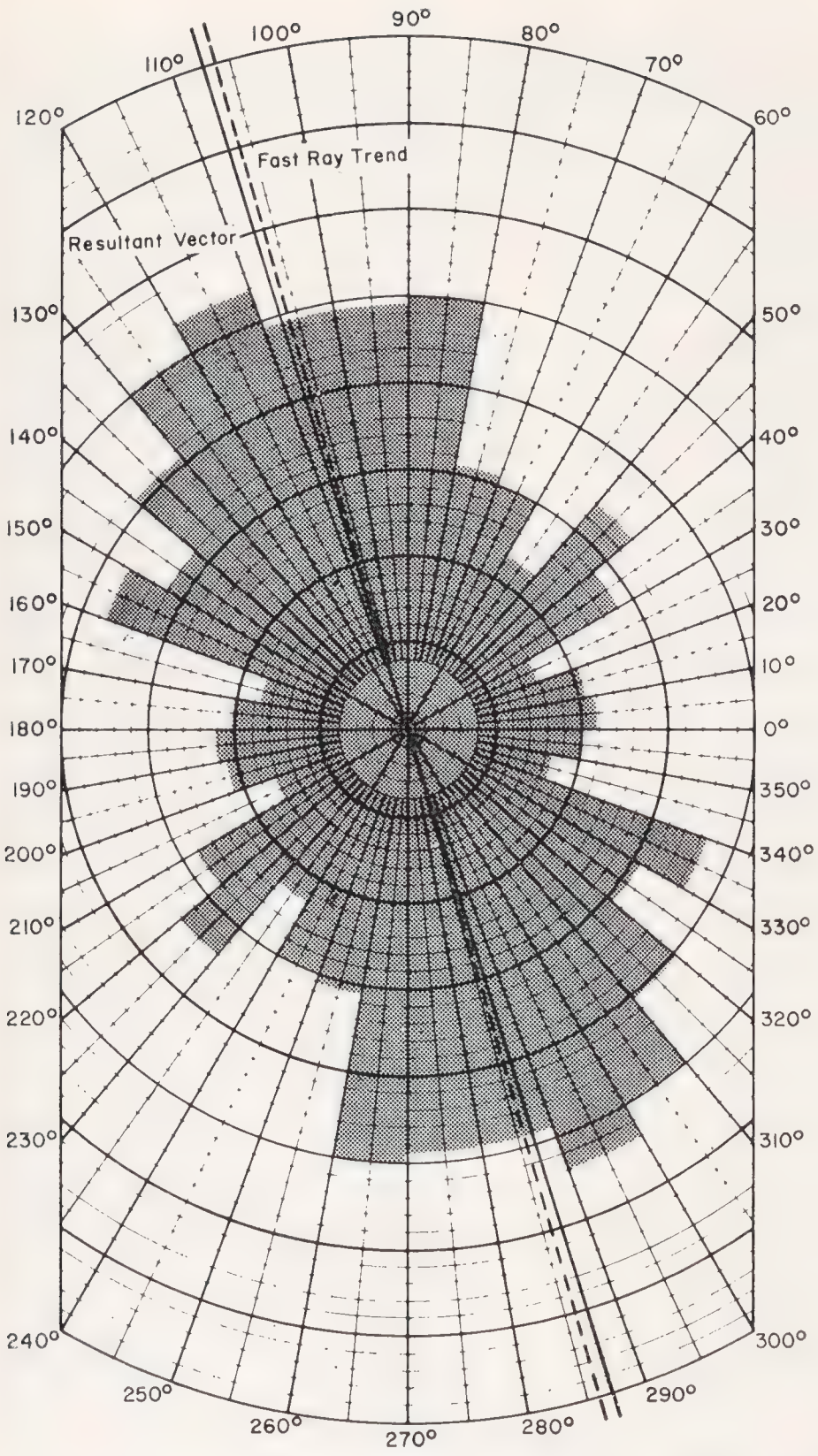

Figure 6. Comparison of the fast ray trend with 604 long axis determinations of feldspar laths in a section of an Oregon basalt.

minations of laths longer than .057 mm along traverses parallel to the horizontal plane. This plot, as would be expected, is much less significant than those of 5a and 5b.

A comparison is given in Figure 6 of the photometrically determined fast-ray trend with 604 long-axis determinations of feldspar (labradorite) laths in an unoriented section of an unidentified Oregon basalt. This basalt is fine-grained having a texture that is in part intergranular and in part intersertal. The long-axis determinations were made along traverses parallel to the 0°-180° line on the plot. Figures 1 and 2, Plate 2, photomicrographs of this basalt in plain light, show that the shape orientation is not obvious. The approximate size of the field included in each photometric determination is indicated in Figure 1, Plate 2. The fast-ray trend in this instance is only 1° from parallelism with the resultant vector.

V. Degree of Orientation

Table 1 lists the magnitude of the orientation[2] for all of the individual measurements expressed in percent of the maximum value. The percent orientation of the resultant vector of the long-axis determinations is also given for each thin-section. Variations in thickness should cause appreciable differences in intensity measurements (Martinez, 1958, p. 602). For this reason these magnitudes were not used in vector determinations.

VI. Conclusions

The data show that for a variety of fine-grained igneous rocks the plagioclases are length-fast in a statistical sense in the measured planes.[3] The angular difference between the fast-ray trend and the resultant vector of the long-axis determinations for

[2] The difference between minimum and maximum intensity.

[3] It has already been indicated that for certain crystallographic habits the plagioclase laths may be statistically length-slow in sections normal to those measured.

Table 1

Degree of Orientation Expressed in Percent

Section No.	Unit	Individual Photometric Determinations							Resultant Vector Magnitude Long-axis Determinations
		Pos. 1	Pos. 2	Pos. 3	Pos. 4	Pos. 5	Pos. 6	Ave.	
CH577A2	Ash Spring basalt No. 2	44	25	36				35	47.0
3.5	Higganum dike	28	18	30				25	67.5
36	Bridgeport dike	23	12	19	20	6	14	16	58.6
35	Bridgeport dike	19	6	12	11	19	17	14	66.1
40	Hampden basalt	11	6	19	5	10	17	11	37.4 & 48.5*
366	Oregon basalt	17	6	7	9	15	16	12	23.1

* Resultant vector magnitude of distribution shown in Figures 5a and 5b.

the various sections was: 1°, 1°, 2°, 4°, and 8° to 10°. Only for the Hampden basalt was the angular difference (8° to 10°) appreciable. Only in the section of Ash Spring basalt were most of the individual grains length-fast. In the other sections the relationship was only statistical.

It seems reasonable to conclude from the data that the feldspar in the Ash Spring basalt is either flattened parallel to (010) or elongated parallel to *a*. For the basalts in which the plagioclase is labradorite, it is considered most likely that the feldspar is tabular on (010).

The results from this representative group of sections also indicate that major flow patterns which produce a planar orientation, readily can be deduced.[4] The oriented sections are all cut normal to and very near or adjacent to contacts. The large change in flow velocity normal to the contact in this zone would be expected to produce a strong preferential orientation (Balk, 1937). The section from the Big Bend National Park probably is also cut normal to the contact. The orientation of the Oregon basalt is not known. The preferential orientation in sections normal to contacts is often so strong that it can be detected by eye. Even for such sections, however, the use of the photometer is advisable as it provides objective and possibly semi-quantitative data. A small angular difference was consistently found to exist between the contact and the preferential orientation, either as directly measured or inferred from photometer measurements. If this can be demonstrated from further studies to be a general condition, somewhat analogous to imbrication in sediments, it might be possible to deduce the direction of flow from sections cut normal to the contact. It is also possible that sections parallel[5] to the contact may be useful for such a purpose. If the feldspars are tabular parallel to (010) many of the (010) planes should be aligned parallel to the contact but those that are not may be rotated by changes in the flow velocity parallel to the contact. This lineation or alignment (possibly in a plane of foliation) should indicate current direction. It seems most likely that this lineation would be identical with a fast-ray trend. Such a lineation, however, can be detected by photometric measurements of the type described whether it is parallel to a fast or slow-ray trend. A study is under way in which flow directions inferred from photometric data will be compared to flow directions inferred from bent pipe amygdules. One of the units being examined is the Hampden basalt.

The principal conclusion derived from this study is that rational and consistent relations exist between the fast-ray trend and shape orientation in certain feldspars. This fast-ray trend can be determined by photometric means. Major flow patterns can thereby be deduced. It is possible that minor flow patterns reflecting flow direction can also be derived.

[4] From universal stage measurements of the orientation of (100) and (010) planes of plagioclase laths, Brinkman (1957) concluded that the microstructure of basalts gives a picture of flow in the melt.

[5] It is not necessary for such sections to be taken near the contact. Better results may be obtained for sections far from the contact.

VII. Acknowledgments

The section of the Higganum dike used in this study was supplied by Mr. Barre Alan Seibert, who had studied this unit as an undergraduate at Wesleyan University. Dr. Ross Maxwell of the Bureau of Economic Geology of the University of Texas made available the section of lava from the Big Bend National Park. Dr. Joe Webb Peoples and Dr. J. R. Balsley of Wesleyan University were of assistance in allowing the writer use of certain facilities there. Dr. Randolph W. Chapman of Trinity College very kindly pointed out appropriate outcrops of the Hampden basalt containing bent pipe amygdules. He was also very helpful in outlining the geology and petrography of this unit. Special thanks are given to Mr. J. G. Rabinowitz of the Clairex Corporation for suggesting and providing the photocell used in this study. Some years ago, Dr. A. E. Sandberg of Louisiana State University suggested that the author might extend his photometric studies to an investigation of igneous rocks. Special thanks are due for this suggestion and other help and inspiration from Dr. Sandberg.

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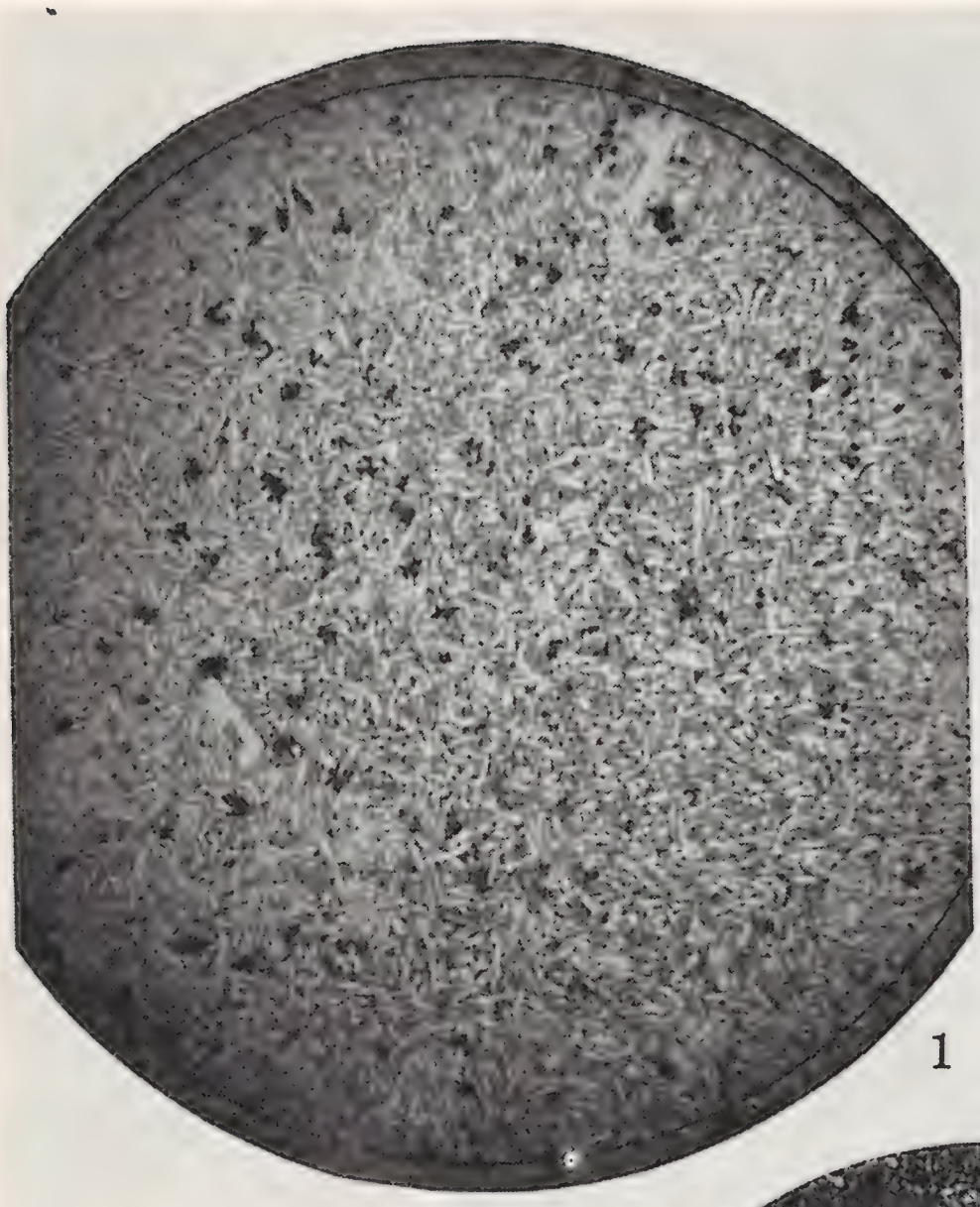
PLATE 1

1. (upper left) Photocell mounted in its adapter.
2. Clairex Corporation number CL503AL photocell.
3. Equipment used for photometric determinations: voltage regulator at left center, ohmmeter at bottom center, adapter for photocell surmounting microscope, and light filter in substage.



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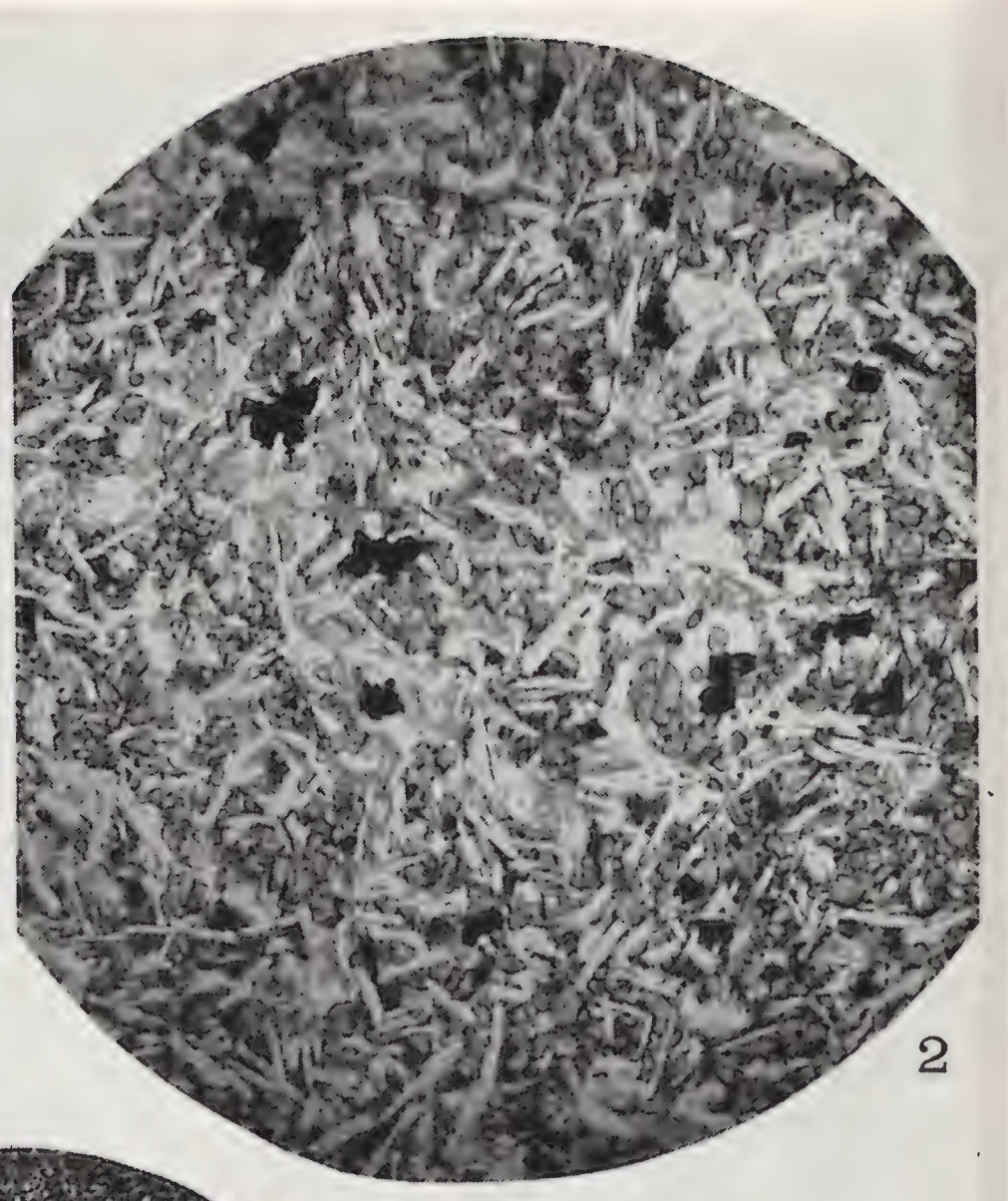

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Plate 2

1. Photomicrograph of thin-section from the unidentified Oregon basalt in plain light, X14. Circle indicates approximate size of field included in a photometric determination.
2. Photomicrograph of thin-section from the unidentified Oregon basalt in plain light, X39.
3. Photomicrograph of thin-section from the Higganum dike. X-Nicols. Diameter of field is approximately 5.5 mm.

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PALEONTOLOGICAL NOTE

CENOZOIC VERTEBRATES FROM THE GULF COASTAL PLAIN—I

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TULANE UNIVERSITY AND
UNIVERSITY OF SOUTH ALABAMA

This report notes two small marine Tertiary vertebrate faunas from east-central Mississippi including the first reported Oligocene sirenian from the southeast. Also reported is the second occurrence of a Middle Eocene sirenian from southwestern Alabama.

The Mississippi material is from the Chickasawhay Formation, and the Red Bluff Formation. The Alabama sirenian is from the Gosport Formation. All material is deposited in the Vertebrate Paleontology Collection of Tulane University (TU). Stratigraphic correlation follows Murray (1961) unless otherwise stated. All sirenian material has been turned over for further study to Roy H. Reinhart, Miami University, Oxford, Ohio.

The Chickasawhay material was collected from an exposure along the banks of the Chickasawhay River, approximately 2½ miles south of the town of Waynesboro, Wayne County, Mississippi. The site is approximately 250 feet upstream from the bridge on Mississippi Highway 63 on the northeast bank, below Waynesboro. It is exposed only at low water level. The site appears the same as Station 13388 of Mansfield (1940). Included in this deposit are remains of an unidentified sirenian, sharks, rays, a teleost, and a turtle.

The sirenian is represented by one complete rib (Plate 1, figure 1), more than 25 rib fragments, a partial vertebra (Plate 1, figures 2a, b) consisting of the centrum and parts of the neural arch, and smaller scraps. The complete rib is 326 mm along the outside curve, and averages about 25 mm in thickness. Most of the rib fragments are of the same thickness, although a single piece (110 mm long) is 40 mm thick. The centrum of the vertebra is 32 mm deep (ventral surface to base of neural canal), 56 mm wide, and 32 mm long (anterior to posterior surfaces). The lot is catalogued as TU 1001.

Associated with the sirenian remains were several identifiable vertebrate elements (TU 1002), including: shark teeth (*Odontaspis* sp.), fragments of ray dental batteries (*Aetobatis* sp.), a catfish spine (Siluroidea), and isolated teeth referable to *Syhpraena* sp. (Mugiloidea). Also associated is a single pleural plate of a trionychid turtle (Plate 1, figures 3a, b), indistinguishable from that of Recent *Trionyx* of a similar size. A second turtle (?) fragment is not from a soft-shelled turtle, but is otherwise unidentifiable. Associated invertebrate fossils are deposited in the Paleontological Collections of the Department of Geology, Tulane University, Locality 242.

A second unidentifiable sirenian rib fragment (TU 1003) is from the Red Bluff Formation, exposed on the east bank of the Chickasawhay River at Hiwanee, Wayne County, Mississippi. Determination of the fragment as sirenian is made on the basis of the density of the bone. Also identifiable in the same collection are isolated teeth of *Odontaspis* sp. and *Sphyraena* (?). Invertebrate associates from the same deposit are catalogued as Locality 226, Paleontological Collections, Department of Geology, Tulane University.

The Eocene sirenian is also represented by a rib fragment (TU 1004) collected at the Gosport Formation exposure on Little Stave Creek, Clarke County, Alabama, as figured in Russell (1955). Recently, Siler (1964)

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May 25, 1965

reported a similar unidentified sirenian rib fragment from the Gosport Formation in Monroe County, Alabama, approximately 40 miles east of the site of the present report. These two Alabama fragments apparently represent the earliest sirenian remains known.

Classically both the Chickasawhay Formation and Red Bluff Formation are considered Oligocene (Mansfield, 1940; Cooke, *et al.*, 1943). Mumma (1965) assigns the Chickasawhay to lowest Miocene. Miocene dugongs *(Hesperosiren)* from the Hawthorn Formation of Florida are well known, though none has been reported from the Suwanee Limestone, the peninsular equivalent of the Chickasawhay (Ray, 1957). The Red Bluff Formation is lowest Oligocene and, as such the sirenian fragment reported represents the first Oligocene specimen from the southeastern United States. Sirenians reported from the western hemisphere Oligocene include a dugong *Caribosiren* (Middle Oligocene, Puerto Rico) and unidentified rib fragments from the Oligocene (?) of Chiapas, Mexico (Reinhart, 1959).

This work was supported by funds provided by the National Science Foundation (GB 2458).

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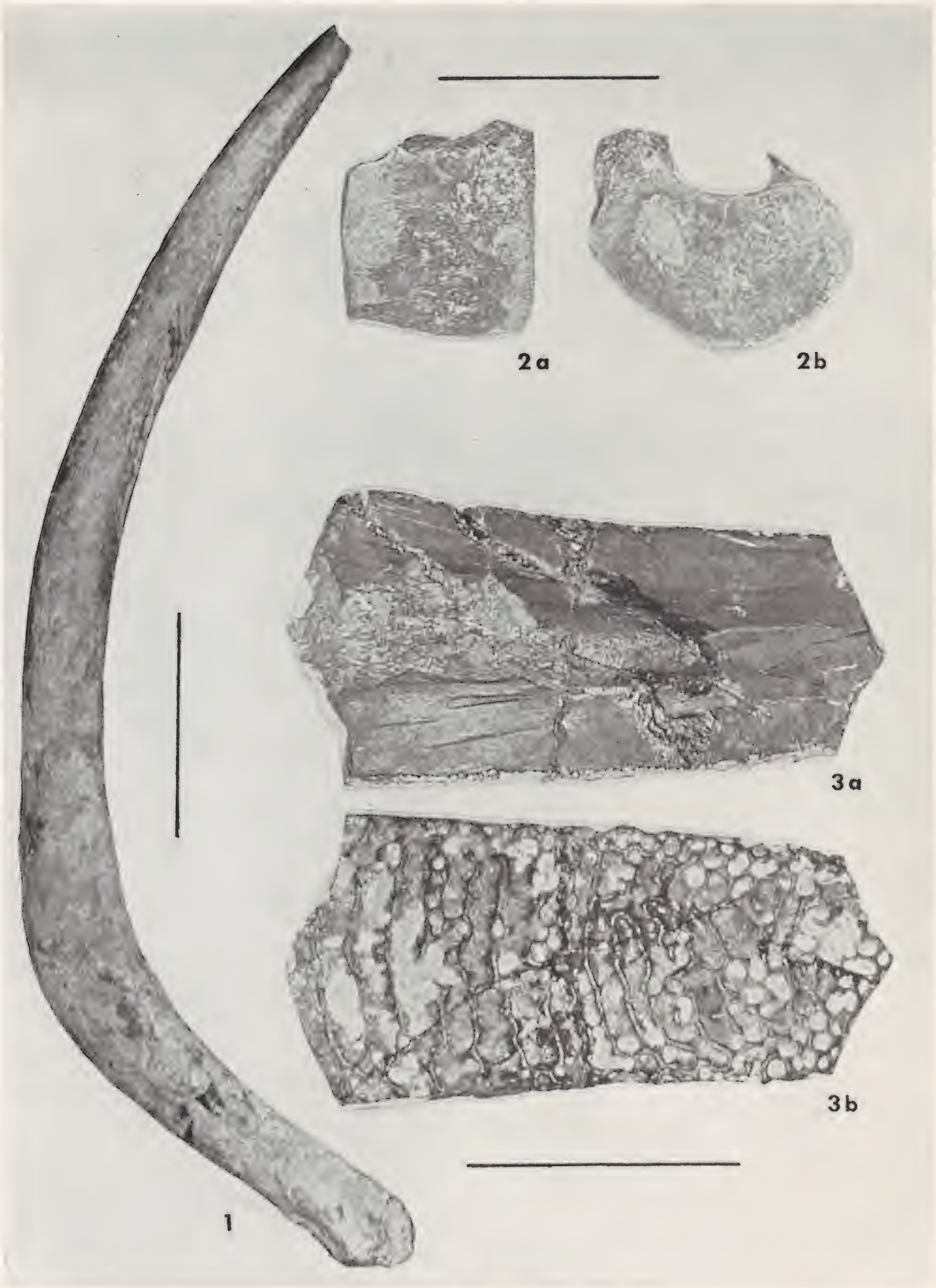

PLATE 1

Vertebrate fossils from the Chickasawhay Formation, Wayne County, Mississippi. 1. Sirenian rib. 2. Sirenian vertebra; a, lateral, and b, anterior aspects. 3. Trionychid pleural element; a, ventral, and b, dorsal aspects. Each scale represents 50 mm.

REVIEWS

REVIEWS: THE FABRIC OF GEOLOGY; THE FOUNDERS OF GEOLOGY; ILLUSTRATIONS OF THE HUTTONIAN THEORY OF THE EARTH

HUBERT C. SKINNER
PROFESSOR OF GEOLOGY
TULANE UNIVERSITY

THE FABRIC OF GEOLOGY, Claude C. Albritton, Jr., *Editor.* Originally published by Addison-Wesley Publishing Company, Inc., Reading, Massachusetts, 1963, x + 372 pp., illustrated.

Second printing with corrections: Freeman, Cooper, & Company, Stanford, California, 1964, x + 374, pp., illustrated. [With "Notes on the Contributors" added to the text.]

The history of geologic thought is reviewed and evaluated in the sixteen essays which comprise *The Fabric of Geology,* a volume prepared in compliment to the 75th Anniversary of the Geological Society of America. These distinguished contributions long will serve as an introduction to the history and philosophy of geology and as a guide to its future development. Students will find portions of this book included in required reading lists.

In the first essay, "James Hutton and the Philosophy of Geology," Donald B. McIntyre salutes Hutton as the "Founder of Modern Geology." He reviews Huttonian theory and places it in proper historical perspective. W. H. Bradley in "Geologic Laws" discusses the role of general laws in geology, demonstrating the unique and fundamental position of geology among the sciences. In "Historical Science" George Gaylord Simpson compares the historical aspect of geology with that of the other sciences. David B. Kitts explores in detail "The Theory of Geology." V. E. McKelvey considers "Geology as the Study of Complex Natural Experiments."

Six essays deal with geologic thought within particular branches of earth science: In "Correlation by Fossils," A. O. Woodford describes valid methods of intercontinental correlation using for examples the classic zones and stages of the Jurassic. His concluding paragraphs provide an adequate answer to the anti-typologists. Donald B. McIntyre discusses "Precision and Resolution in Geochronometry." J. Hoover Mackin's "Rational and Empirical Methods of Investigation in Geology" deserves special mention. These methods, often opposed and argued, are given restrained and scrupulously fair evaluation. This essay should be required reading for every graduate student early in his thesis or dissertation research. Mason L. Hill considers the "Role of Classification in Geology" with examples given from the classification of faults. Charles A. Anderson's "Simplicity in Structural Geology" deals with the application of Occam's razor to geologic interpretation. "Association and Indeterminacy in Geomorphology" is the subject of Luna B. Leopold and Walter B. Langbein.

Next, Frederick Betz, Jr., discusses "Geologic Communication." In "The Scientific Philosophy of G. K. Gilbert," James Gilluly reviews the considerable contributions of this distinguished American geologist to the methodology of later workers. J. M. Harrison considers the "Nature and Significance of Geological Maps." The "Philosophical Aspects of the Geological Sciences" is treated by Arthur F. Hagner. Robert F. Leggett's "Geology in the Service of Man," traced from remote antiquity through William Smith to the present day, concludes the series of essays.

As editor, Claude C. Albritton, Jr., wrote the preface and the final portion entitled "Philosophy of Geology: A Selected Bibliography and Index," an excellent contribution providing a rich guide to future reading. An index to this bibliography and a subject index to the volume are appended.

The Fabric of Geology is recommended enthusiastically to all geologists and others interested in geologic thought, its history, its evolution, and its philosophy.

THE FOUNDERS OF GEOLOGY, by Sir Archibald Geikie. Published by Dover Publications, Inc., New York, 1962, xi + 486 pp., $2.25. [Reprint of the second edition of 1905.]

In 1896, Sir Archibald was invited by the president of Johns Hopkins University to inaugurate the Lectureship founded in memory of George Huntington Williams, late Professor of Geology in that institution. He chose for his subject "an outline of the history and development of geology during the period between the middle of the eighteenth and the close of the second decade of the nineteenth century — an interval of about seventy years, full of peculiar interest to students of the science, for it was during that interval that the main foundations of modern geology were laid."

In 1897, the series of six lectures was published entitled *The Founders of Geology.* Later, in preparing a second edition, Sir Archibald extended his coverage to include the "earlier progress of geological ideas, from the times of ancient Greece onwards" and departed from the original lecture form to develop his subject more fully. It is this second edition which has been reprinted from the original by photo-offset-lithography, a process which reproduces faithfully with little chance for error of transcription. This pitfall is illustrated by the cover of the reprint which is emblazoned with the words "BY SIR *ANDREW* GEIKIE!" It seems strange that the publisher has not yet discovered and corrected this error.

The Founders of Geology is a classic in its field. It is well-written, informative, and quite readable. It has been out of print for many years and copies have commanded a high price on the used book market. This inexpensive reprint will be welcomed by everyone interested in the history of geology.

ILLUSTRATIONS OF THE HUTTONIAN THEORY OF THE EARTH, by John Playfair. Published by Dover Publications, Inc., New York, 1964, xl + 528 pp., $2.75. [Republication of the facsimile reprint (University of Illinois, 1956) of the 1802 edition.]

This work is one of the great milestones in the history of geology. It was first reprinted in 1956 prefaced by an introduction and biographical sketches of both Hutton and Playfair written by Professor George W. White of the University of Illinois. Its popularity is demonstrated by the rapid appearance of this second reprint which is well-done and pleasing.

James Hutton's classic *Theory of the Earth, with Proofs and Illustrations,* was published in 1795, shortly before his death. In this work Hutton's brilliant statements were obscured by his prolix and ponderous prose. Thus, for some years it attracted little notice. Fortunately for the geological sciences, the mathematician John Playfair, close friend, biographer, and champion of Hutton, was moved to write and publish a summary of and commentary on the *Theory.* His *Illustrations of the Huttonian Theory of the Earth* is the result. Three sections of the book (140 pages) are devoted to a summary of Hutton's theory. In the remaining 388 pages of "Notes and Additions" Playfair clarifies and extends the *Theory* and introduces his own important original observations. Playfair's mastery of English, his orderly and lucid style, and his own enormous contributions to geologic thought are combined into this volume with literary qualities rarely equalled in all scientific writing.

The eloquent comments on Playfair and his work by Sir Archibald Geikie (*The Founders of Geology*, 1905) cannot be improved: "Gifted with a clear penetrating mind, a rare faculty of orderly logical arrangement, and an English style of altogether remarkable precision and elegance, he was of all men best fitted to let the world know what it owed to Hutton. . . . His volume appeared in the spring of 1802, just five years after Hutton's death, with the title of *Illustrations of the Huttonian Theory of the Earth.* Of this great classic it is impossible to speak too highly. After the lapse of a century it may be read with as much profit and pleasure as when it first appeared. For precision of statement and felicity of language it has no superior in English scientific literature. To its early inspiration I owe a debt which I can never fully repay. Upon every young student of geology I would impress the advantage of reading and re-reading, and reading yet again this consummate masterpiece. How different would geological literature be to-day if men had tried to think and write like Playfair!"

May 25, 1965

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PART II—CHICOREUS *sensu stricto* AND CHICOREUS (SIRATUS)
EMILY H. VOKES
TULANE UNIVERSITY p. 181

NOTE ON THE AGE OF THE CHIPOLA FORMATION (MIOCENE) OF NORTHWESTERN FLORIDA
EMILY H. VOKES
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CENOZOIC MURICIDAE OF THE WESTERN ATLANTIC REGION

Part II—Chicoreus *sensu stricto* and Chicoreus (Siratus)

EMILY H. VOKES
TULANE UNIVERSITY

CONTENTS

I. Abstract 181
II. Introduction 182
III. Acknowledgments 183
IV. Systematic Descriptions 184
V. Notes on Recent Species of *CHICOREUS (SIRATUS)* 195
VI. Rectifications in Nomenclature for Part I—*MUREX* s.s. 197
VII. Appendix I: References for Species Cited 197
VIII. Appendix II: Locality Data 198
IX. Literature Cited 200

ILLUSTRATIONS

Text Figure 1 186
Text Figure 2 191
Plate I 199
Plate II 201
Plate III 203

I. Abstract

There are 12 presently known species of the gastropod subgenus *Chicoreus* sensu stricto (type: *Murex ramosus* Linnaeus) from the Cenozoic of the western Atlantic region. Five of the species are Recent, of these three are known also as fossils, and the balance are known only from the fossil record. In this paper all of the species are treated systematically, including one new species, *Chicoreus (Chicoreus) floridanus* E. H. Vokes. It is suggested that the oldest representatives of the group are derivatives of European species described from the Helvetian beds of western Europe.

In addition, those muricine species formerly assigned to a "Western Atlantic" subgroup of *Murex* s.s. are here placed in the subgenus *Chicoreus (Siratus)*. Two specific homonyms in this group are renamed, they are: *C. (Siratus) perelegans* (*n.n.* pro *Murex elegans* Sowerby, *non* Donovan), and *C. (Siratus) reevei* (*n.n.* pro *Murex trilineatus* Reeve, *non* Sowerby).

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II. Introduction

The genus *Chicoreus* (type species: *Murex ramosus* Linnaeus) was first proposed in 1810 by Denys de Montfort (p. 611) to include those species, formerly assigned to the genus *Murex* Linnaeus, 1758, which were to be distinguished by having:

> "Coquille libre, univalve, à spire élevée et feuillée; bouche arrondie; columelle lisse; lèvre extérieure armée, frisée et crépue; canal de la base large et recouvert par la prolongation de la columelle."

Although the species illustrated by Montfort for *Murex ramosus* is *Murex brevifrons* Lamarck, there is no question that Montfort was using the name *"ramosus"* in a polyspecific sense and, therefore, the type of *Chicoreus* is the shell to which the name *ramosus* has been subsequently restricted by later authors. (For further discussion, see Vokes, 1964, p. 7-8.) Keen (1964, p. 422) recently placed a petition before the International Commission on Zoological Nomenclature to have *Murex ramosus* fixed as the type of *Chicoreus* to clarify the situation.

Although *Chicoreus* sensu stricto is perhaps the largest single group in the subfamily Muricinae, its distribution is largely Indo-Pacific, and there are only a few western Atlantic representatives, either Recent or fossil. There are only five species of *Chicoreus* s.s. in the Recent fauna: *C. brevifrons* (Lamarck), *C. florifer* (Reeve), *C. dilectus* (A. Adams), *C. argo* (Clench and Pérez Farfante) and *C. spectrum* (Reeve). The fossil record is scarcely better, only nine species being recognized in this paper, two of which are also Recent or a total of 12 species in the western Atlantic.

The first western Atlantic species of *Chicoreus* s.s. appear in the Miocene Chipola Formation of northwestern Florida and its correlatives. Although this formation has been generally considered to be uppermost lower Miocene (Burdigalian) in age, the presence in this formation of four species of *Chicoreus* which are closely related to species in the Helvetian of Europe suggests a change of age for the formation. This problem is discussed more thoroughly in a companion paper immediately following this one. For the purposes of this paper the generally accepted age for the Chipola will continue to be used, but with a query, indicating that there is doubt in the mind of the writer as to its validity.

There have been no *Chicoreus* s.s. reported from the Shoal River Formation, nor the Oak Grove Sand, both of which may be only facies of the Chipola (Vernon, 1942, p. 75). The lack of *Chicoreus* is probably due to environmental control, as both of these formations are sandy, and *Chicoreus* seems to prefer a limy or silty bottom. In other Miocene localities throughout the western Atlantic region *C. cornurectus* (Guppy) is the most widespread species. Two other species, *C. compactus* (Gabb) from the middle Miocene of Santo Domingo, and *C. venezuelanus* (F. Hodson) from the middle Miocene of Venezuela, are only locally represented. In the upper Miocene of Florida a new species appears, *C. floridanus* Vokes, n. sp., a descendant of *C. dujardinoides* of the Chipola Formation. This species immediately became abundant throughout Florida, although it is not known from Caribbean localities. The line has persisted in the Recent form, *C. dilectus* (Adams). In the more southern area *C. brevifrons* (Lamarck) appears in the Pliocene, and today is found throughout the Caribbean.

The *Chicoreus* s.s. line evidently originated in the Tethyan Sea during early Miocene time. From *Murex tricarinatus* Lamarck, a common species in the middle and upper Eocene of western Europe, it is a simple step to derive the first *Chicoreus* species, for in *M. tricarinatus* the winglike varices are beginning to show a trend toward digitation, which ultimately form the elaborate frondose varices typical of *Chicoreus* s.s. (The *Chicoreus (Siratus)* group which seems to be an endemic western Atlantic form probably developed from a comparable American Eocene species, and thus may represent parallel evolution rather than true relationship.) From the Tethyan area of origin the group spread to the western Atlantic, and via the upper Miocene central European basins to the eastern Pacific, but not across the Pacific to the western coast of America. Strangely the *Chicoreus* group did not pass through the Isthmian channel which was open at various times both in Panama and in the Tehuantepec region, although other members of the Muricidae made the transition. (On the West Coast of the Americas the *Phyllonotus* and *Hexaplex* groups are dominant, as are the mem-

bers of the subfamily Tritonaliinae, to the complete exclusion of *Chicoreus*. *Murex* sensu stricto is represented by only two or three species but they are locally common.)

Chicoreus s.s. is a subtropical shallow water group, with the members generally inhabiting depths of less than 50 fathoms. A non-rocky bottom seems to be preferred, and some species even live in mangrove swamps. The members are carnivorous, attacking their prey by means of a hole bored in the shell. (One specimen of *C. dilectus,* dredged by the writer, was actively engaged in boring such a hole in a *Chione cancellata.* Such persistence was displayed by the snail that it did not release its prey until both were dropped into alcohol.) Due to the shallow, soft-sediment environment preferred by these animals, they are readily preserved as fossils, and although there are only a few species in the western Atlantic Tertiary, they are a common element in the fauna wherever they occur.

In addition to *Chicoreus* sensu stricto there are two subgenera of *Chicoreus* which seem to be endemic western Atlantic forms, and in these groups, *Siratus* (type species: *Murex senegalensis* Gmelin) and *Phyllonotus* (type species: *Murex margaritensis* Abbott, new name for *Murex imperialis* Swainson, *non* Fischer), there are numerous western Atlantic species, both Recent and fossil. The subgenus *Siratus* includes many species heretofore placed in the genus *Murex* s.s. In the previous part of this work (Vokes, 1963a) these species were allocated to a "Western Atlantic" group of *Murex* s.s., for it was believed that the two forms should be distinguished. Subsequent work has convinced the writer that those species which have a deflected siphonal canal and a tendency toward alate varices, are to be included in the subgenus *Siratus* rather than *Murex* s.s. This decision was discussed further by the author in another work on supraspecific groups of the Muricidae (Vokes, 1964, p. 9). Some of the fossil species from the western Atlantic which were treated in the *Murex* s.s. portion of this monograph therefore should be assigned to *Chicoreus (Siratus).* They are *Murex quirosensis* F. Hodson, *M. gardnerae* E. H. Vokes, *M. chipolanus* Dall, *M. gilli* (Maury), *M. gilli polynematicus* Brown and Pilsbry, *M. nicholsi* Gardner, and *M. antillarum* Hinds. The reader is referred to section V of this paper for a discussion of the Recent species now considered *Chicoreus (Siratus).* The species of the subgenus *Phyllonotus* are sufficiently numerous to be treated in a separate part of this monograph and will follow next in publication. Therefore the only species that will be covered systematically in this section are those of the subgenus *Chicoreus* s.s.

As in the previous part of this work (Vokes, 1963a) the author has tried to include all pertinent references to the fossil representatives, but the synonymies do not include all references to the Recent citations, for three of the species are very common and to list all references would extend the synonymies unnecessarily.

III. Acknowledgments

The writer wishes to express her gratitude to a number of persons who aided in the preparation of this paper. Especially she would like to thank Norman Tebble and Peter Dance of the Mollusca Section, British Museum (Natural History), for their many kindnesses both during her stay at that institution and subsequently. She would also like to thank the Trustees of the British Museum (Natural History) for permission to photograph many of the specimens in the collections of the Museum. G. Arthur Cooper and Harald A. Rehder, both of the U. S. National Museum; Rudolf Trümpy, of the Swiss Federal Technical Institute and the University of Zürich; and Katherine V. W. Palmer, of the Paleontological Research Institution, all loaned specimens essential to this study. Anna M. Bidder, of the Department of Zoology, Cambridge, (England); Arthur N. Dusenbury, Jr., of White Plains, New York; Norma F. McMillan, of the Liverpool Museum, Natural History Department; and L. R. Cox, of the British Museum (Natural History), provided necessary information. Finally she is very grateful to the members of the editorial committee: Druid Wilson, of the U. S. Geological Survey; Katherine V. W. Palmer, of the Paleontological Research Institution; and Myra Keen, of Stanford University, for their many useful suggestions and comments.

IV. Systematic Descriptions

Phylum Mollusca
Class Gastropoda
Subclass Prosobranchia
Order Neogastropoda
Suborder Stenoglossa
Family Muricidae
Subfamily Muricinae
Genus Chicoreus Montfort, 1810
Subgenus Chicoreus s.s.

Chicoreus (Chicoreus) folidodes (Gardner)

Plate I, figures 1a, b.

Murex trophoniformis Heilprin. Dall, 1890, Wagner Free Inst. Sci., Trans., v. 3, pt. 1, p. 140 (in part, *not* of Heilprin).

Murex trophoniformis Heilprin. Dall, 1915, U. S. Natl. Mus. Bull. 90, p. 74 (in part, *not* of Heilprin).

Murex (Chicoreus) folidodes Gardner, 1947, U.S.G.S. Prof. Paper 142-H, p. 520, pl. 53, fig. 5.

Diagnosis: "Shell of moderate dimensions, rather heavy, stout fusiform, the maximum diameter falling in front of the median horizontal. Aperture little more than half as high as the entire shell. Whorls of conch probably 7, the early volutions broadly convex, the body increasing less rapidly in diameter than the whorls of the spire; the posterior margin of the closely appressed later volutions creeping up a little on the preceding whorl. Protoconch imperfectly preserved; final whorl small and smooth, somewhat flattened laterally. Axials on the early volutions narrow, well rounded, retractive, arranged in series slightly off set at the suture and performing about half a turn, increasing in prominence toward the anterior suture, equal and separated by concave interspaces of approximately their own width, commonly 9. Varices developed by the strengthening of every third rib, the costal to the right of the varix becoming increasingly feeble and finally obsolete, the costal to the left of the varix, gradually transformed into a rather prominent peripheral node; varices on the later whorls foliaceous, the free edges sharply fluted in a series of short, serrate processes, open toward the aperture; the primary spirals forming the axes of the spines; spines tending to lengthen anteriorly, most produced on the pillar. Entire surface except the apical region macroscopically shagreened by the sharp laminar incrementals, numbering about 4 to the millimeter over the greatest part of the adult shell; the free edges worn down in the type but probably in fresh specimens finely fluted by the spirals, even by the secondaries and tertiaries. Spiral sculpture well developed. Primary spirals 5 on the whorls of the spire, 13 or 14 on the body and pillar, rather angular and separated on the posterior portion of the shell by angular interspaces, equally prominent on the costals and intercostals, but more elevated toward the anterior suture; linear secondaries intercalated between each pair of primaries on the third or fourth whorl of the conch, the number of intercalated secondaries increased on the fifth whorl to 2, on the final whorl of the spire to 3 or 4, and on the periphery of the body to 4 or 5, the medial secondary usually stronger than those on either side. Anterior fasciole not well differentiated, threaded with 9 or 10 subequal lirae. Aperture exclusive of the canal obliquely elliptical, emarginate posteriorly. Curvature of outer lip a little broader than that of the inner; margin of outer lip sharply crenate in harmony with the spiral sculpture, the interspiral channels showing up on the inner surface as low ridges and produced for some little distance within the mouth of the aperture. Labium smoothly excavated at the base of the body, heavily glazed. Pillar margin sharply rounded at the entrance to the canal. Anterior canal broad, compressed dorsoventrally, curved backward, obliquely truncate at its extremity, probably closed in the perfect adult; former canals, one to each varix, quite sharply divergent from the final canal." (Gardner, 1947)

Holotype: USNM 371852.

Dimensions of holotype: height 43.3 mm, diameter 25 mm.

Type locality: USGS 3419 (= TU 457), one mile below Bailey's Ferry, Chipola River, Calhoun County, Florida.

Horizon: Chipola Formation, Florida; (?) uppermost lower Miocene.

Figured specimen: USNM 644821, height 42 mm, diameter 24.8 mm; locality TU 554. Other occurrences: TU locality no. 457.

Discussion: The affinities of this species and *C. lepidotus* (Vokes), both from the Chipola Formation of northwestern Florida, have been discussed by this author in a previous work (Vokes, 1963b, p. 154). It should also be noted that *C. folidodes* resembles *C. aquitanicus* (Grateloup) from the Helvetian and Tortonian of Europe, differing principally in the larger size and more elongate shell of the European species. *C. aquitanicus* may further be distinguished by the presence of two intervarical nodes rather than one, characteristic of *C. folidodes.* The strongest resemblance lies in the surface ornamentation of the two species, for both possess a spiral ornamentation consisting of strong cords, separated by one smaller thread, and two threadlets between each pair. The spiral cords are crossed by minute growth lines which give rise to a shagreened surface. *C. aquitanicus* is figured (plate I, figure 2) for comparison with the American

species. The stratigraphic significance of this resemblance is discussed in the companion paper which immediately follows this one.

CHICOREUS (CHICOREUS) LEPIDOTUS (Vokes)

Plate I, figure 4.

Murex (Chicoreus) lepidotus E. H. VOKES, 1963, Tulane Stud. Geol., v. 1, no. 4, p. 152, pl. 1, figs. 2a, 2b.

Diagnosis: "Shell large in size, whorls convex. Nucleus of two smooth, slightly bulbous whorls; termination of nuclear whorls marked by abrupt initiation of ornamentation. Seven post-nuclear whorls in the adult, suture appressed. Axial sculpture consists of ten equal nodes on the early whorls; on the third and successive post-nuclear whorls certain of these are strengthened to form four varices, with a single intervarical node between each pair. Spiral sculpture consists of primary threads, three in number on the earliest whorls, increasing to approximately six on the body whorl, with three additional primary threads on the pillar. Intercalcated between the primary threads are one secondary, and usually two tertiary threadlets. Entire surface of shell sculptured by minute laminar incrementals which give a shagreened appearance to the intervarical areas. The free edges of the varices are sharply fluted by a succession of laminae with small open spinelets produced where the primary threads cross the varices. Two series of slightly larger spines are developed on the siphonal canal where the primary threads cross. Aperture subcircular; labium smooth, standing free at the anterior end, appressed at the posterior, with slight anal notch. Outer lip crenulated by about 12 paired denticles. Siphonal canal moderately long, broad and sharply recurved at tip; former canals conspicuously divergent." (Vokes, 1963)

Holotype: USNM 644371.

Dimensions of holotype: height 34 mm, diameter 20 mm.

Type locality: TU 554, Chipola River, at power-line crossing (SW ¼ Sec. 17, TIN, R9W), Calhoun County, Florida.

Horizon: Chipola Formation, lower beds only, Florida; (?) uppermost lower Miocene.

Figured specimen: USNM 644371 (holotype). Other occurrences: TU locality no. 457.

Discussion: This species was discussed in the original description. Since that time the author has had the opportunity to examine a collection of European Miocene fossils and the resemblance to *C. bourgeoisi* (Tournouër) should be noted. (See plate I, figure 3.) The European species bears the same relationship to the European *C. dujardini* (Tournouër) as the Florida species does to *C. dujardinoides.* From the literature the two European species would seem to occur together but the parallelism of the forms suggests that perhaps there is a slight stratigraphic difference which has not been detected for the European species.

CHICOREUS (CHICOREUS) DUJARDINOIDES (Vokes)

Plate I, figure 6.

Murex (Chicoreus) lepidotus dujardinoides E. H. VOKES, 1963, Tulane Stud. Geol., v. 1, no. 4, p. 155, pl. 1, figs. 3a, 3b.

Diagnosis: "Shell large in size, whorls moderately convex. Nucleus of two smooth, slightly bulbous whorls; termination of nuclear whorls marked by appearance of ornamentation, both axial and spiral. Seven post nuclear whorls in the adult, suture appressed. Axial sculpture consists of ten equal nodes on the early whorls; on the fourth and successive post-nuclear whorls certain of these nodes are strengthened to form three varices, with two intervarical nodes between each pair. Spiral sculpture consists of primary threads, three in number on the earliest whorls, increasing to approximately seven on the body whorl, with three additional primaries on the pillar. Intercalcated between the primary threads are one secondary, and usually two tertiary threadlets. Entire surface of shell sculptured by minute laminar incrementals which give a shagreened appearance to the intervarical areas. The free edges of the varices are sharply fluted by a succession of laminae with open spinelets produced where the primary threads cross the varices. One larger open spine developed at the shoulder, and two series of large spinelets on the siphonal canal. Aperture subcircular; labium smooth, standing free at the anterior end, appressed at the posterior, with a slight anal notch. Outer lip crenulated with about 12 paired denticles. Siphonal canal moderately long, broad, and sharply recurved at tip; former canals conspicuously divergent." (Vokes, 1963)

Holotype: USNM 644372.

Dimensions of holotype: height 32.5 mm, diameter 18.5 mm.

Type locality: TU 547, Chipola River (SW ¼ Sec. 29, TIN, R9W), Calhoun County, Florida.

Horizon: Chipola Formation, upper beds only, Florida; (?) uppermost lower Miocene.

Figured specimen: USNM 644372 (holotype). Other occurrences: TU locality nos. 458, 453.

Discussion: The affinity of this species to the European species, *C. dujardini* (Tournouër) have been discussed in the original

description. Since that time the author has studied a series of specimens of the French species and in addition to the differences previously mentioned the two species can also be distinguished by the higher spire of *C. dujardini.* This European species is figured here (plate I, figure 5) for purposes of comparison.

C. cornurectus (Guppy), described from the Miocene of Santo Domingo, and *C. dujardinoides* occur in the Chipola Formation, but the two species are readily separable. The spire of *C. cornurectus* is proportionally higher, and the shoulder spine is much more developed. The characteristically shagreened surface of *C. dujardinoides* is not seen in *C. cornurectus,* that species lacking the minute growth lines which cause the peculiar surface texture in *C. dujardinoides* and allied species. Likewise the faces of the varices do not carry the succession of laminae with the small open spines noted in *C. dujardinoides.* The environmental preferences of the two species were evidently somewhat different, for *C. dujardinoides* has been found only at localities along the Chipola River where the formation is a lime-mud and *C. cornurectus* has been found only at the more westward exposures of the Chipola beds where the formation is silty. The localities in the Cercado and Gurabo Formations of Santo Domingo where *C. cornurectus* occurs are also silty and bear a strong lithologic similarity to the silty facies of the Chipola.

Chicoreus (Chicoreus) cornurectus (Guppy)

Plate II, figure 2a, b., text figure 1.

Murex (Chicoreus) megacerus Sowerby. Gabb, 1873, Amer. Phil. Soc., Trans., (N.S.) v. 15, pt. 1, p. 202 (*not* of Sowerby).

Murex cornurectus Guppy, 1876, Geol. Soc. London, Quart. Jour., v. 32, p. 521, pl. 28, fig. 4.

Murex (Euphyllon) cornurectus Guppy. Cossmann, 1903, Essais Paléoconch. Comp., v. 5, p. 25.

Murex cornurectus Guppy. Guppy, 1910, Agri. Soc. Trinidad and Tobago, Paper no. 440, p. 6, 9. Guppy, 1911, Agri. Soc. Trinidad and Tobago, Paper no. 454, p. 8 (*ex* Harris reprint: Bulls. Amer. Paleontology, 1921, v. 8, no. 35, pp. 149 (297), 151 (299), & 164 (312).)

Murex (Phyllonotus) cornurectus Guppy. Maury, 1917, Bulls. Amer. Paleontology, v. 5, no. 29, p. 103 (267), pl. 16 (42), figs. 9, 10.

? Murex (Phyllonotus) cornurectus Guppy. Hubbard, 1921, N. Y. Acad. Sci., Sci. Surv. Porto Rico & Virgin Islands, v. 3, pt. 2, p. 150.

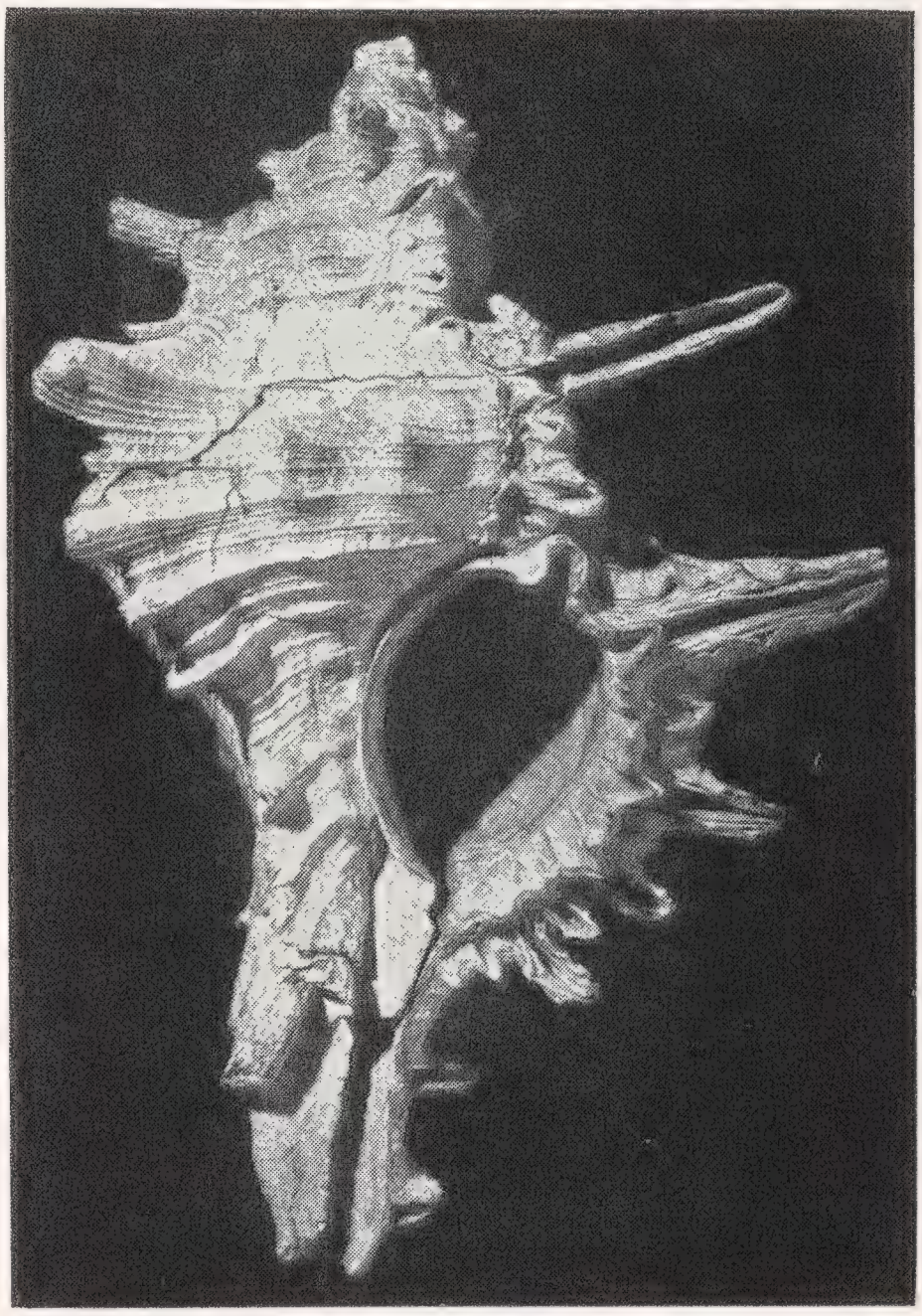
Murex (Phyllonotus) cornurectus Guppy. Olsson, 1922, Bulls. Amer. Paleontology, v. 9, no. 39, p. 131 (303).

Murex (Chicoreus) brevifrons Lamarck. Pilsbry, 1922, Acad. Nat. Sci. Phila., Proc., v. 73, p. 352 (*not* of Lamarck).

Murex brevifrons Lamarck. Maury, 1925, Serv. Geol. Min. Brasil, Mon. 4, p. 138-139, pl. 6, figs. 7, 9 (*not* of Lamarck).

Murex (Phyllonotus) cornurectus Guppy. Maury, 1925, Bulls. Amer. Paleontology, v. 10, no. 42, p. 213 (365).

Murex (Chicoreus) brevifrons Lamarck. Woodring, 1959, U.S.G.S. Prof. Paper 306-B, p. 216, pl. 35, fig. 12 only (in part, *not* of Lamarck).



Text figure 1. *Murex cornurectus* Guppy. (X 1). Lectotype: British Museum (Nat. Hist.) GG. 20254. (Photograph courtesy of the British Museum (Nat. Hist.).)

Diagnosis: "Ovate-turreted, with three varices, which are nearly continuous, and stout revolving ridges accompanied by finer lines; two or occasionally three variciform tubercles between each varix; varices fringed by subtubular spines, of which the one corresponding to the keel on the angle of the whorls is much the longest. Aperture oval, the inner margin callous, the outer margin dentate, the dentations running in pairs. Canal moderately long and slightly curved." (Guppy, 1876)

Lectotype (here designated): British Museum (Nat. Hist.) GG. 20254.

Dimensions of lectotype: height 89.2 mm, diameter, excluding spines, 45 mm.

Type locality: Rio Yaque, Dominican Republic.

Horizon: Quebradillas Limestone, Puerto Rico; Pirabas Limestone, Brazil; Chipola Formation, Florida; Cercado Formation, Dominican Republic; all (?) uppermost lower Miocene. Gurabo Formation, Dominican Republic; Gatun Formation, Panama and Costa Rica; middle Miocene. Springvale Beds, Trinidad; upper Miocene.

Figured specimen: USNM 644822, height 38.5 mm, diameter, excluding spines, 20 mm; locality USGS 8550. Other occurrences: TU locality nos. 70, 196, 655.

Discussion: Like *C. dujardinoides* this species also resembles the European species, *C. dujardini.* The early whorls are especially similar, with both having a strongly cancellate appearance. The spires of *C. cornurectus* and of *C. dujardini* are of like proportions, and are relatively higher than *C. dujardinoides.* As has been discussed under *C. dujardinoides* the surface of *C. cornurectus* is smoother than the other two species and the varices lack the laminar frills, having instead five simple open spines. The shoulder spine of *C. cornurectus* is much more developed and the species attains a larger size. A small specimen is figured (plate II, figs. 2a, b) which shows the nature of the early whorls particularly well. The lectotype is of a more normal size.

There are two syntypes in the Geological Society of London collections now to be found at the British Museum (Natural History). Dr. L. R. Cox of the Museum writes *(in litt.),* "The smaller of the two, now registered as no. GG.20253 is the one represented in Guppy's plate xxviii, fig. 4, but the larger one, no. GG.20254 is better preserved and would make a better lectoype if only it were figured. Presumably Guppy figured the smaller one because there was not enough room for the larger one on his plate. The two are undoubtedly the same species." Therefore the larger specimen, no. GG.20254, is here selected as the lectotype and is figured in text figure 1.

Although this species has been placed in synonymy with *C. brevifrons* (Lamarck) by some authors the two forms are readily distinguishable. *C. cornurectus* has but one strong spine at the shoulder and *C. brevifrons* has two equally large spines with one small spinelet between them. *C. cornurectus* has four smaller spines on the anterior portion of the varix, and *C. brevifrons* has only three. Therefore even though the total number of varical spines is the same for the two species, the difference in size of the second shoulder spine permits instant recognition. *C. cornurectus* is the ancestor of *C. brevifrons,* but little is to be gained by placing the two forms in synonymy. *C. argo* (Clench and Pérez Farfante) and *C. spectrum* (Reeve) both Recent species from the Lesser Antilles are perhaps even more closely related to *C. cornurectus* as they differ only in having three smaller anterior spines in place of the four of *C. cornurectus.*

In addition to the many Miocene localities in the Caribbean where this species has long been known and is not rare, it recently has been found by the writer in the upper beds of the Chipola Formation of northwestern Florida. Although this new find does not extend the geological range of the species, it does extend the geographical range considerably. Hubbard (1921) reported finding a portion of an external mold in the Quebradillas Limestone of Puerto Rico which may be this species, and Maury (1925a) reported it from the Pirabas Limestone of Pará, Brazil, as *M. brevifrons.* Both of these formations are correlated with the Chipola. Maury (1917) reported that this species was found in both the lower formation (Cercado) and the upper formation (Gurabo) in Santo Domingo. It has also been reported from the middle Miocene Gatun Formation of Costa Rica by Olsson (1922), and Woodring (1959) reported a *"Murex brevifrons"* from the Gatun Formation of Panama which seems in part to be *C. cornurectus.* His illustrations are of two species, the smaller specimen (pl. 35, fig. 12) being *C. cornurectus.* The larger specimen (pl. 35, figs. 11, 13) is not either *C. cornurectus* or *C. brevifrons,* but it is too poorly preserved to identify positively. The species has also been reported from the upper Miocene beds at Springvale, Trinidad, by Guppy (1910, 1911) and by Maury (1925b).

Chicoreus (Chicoreus) compactus (Gabb)

Plate II, figure 3a, b.

Murex (Pteronotus) compactus Gabb. 1873, Amer. Phil. Soc., Trans., (N.S.) v. 15, pt. 1, p. 202.

Murex textilis Gabb. Guppy, 1876, Geol.

Soc. London, Quart. Jour., v. 32, p. 522 (in part, *not* of Gabb).

Murex (Pteronotus) textilis Gabb. DALL, 1890, Wagner Free Inst. Sci., Trans., v. 3, pt. 1, p. 142 (in part, *not* of Gabb).

Murex compactus Gabb, MAURY, 1917, Bulls. Amer. Paleontology, v. 5, no. 29, p. 103 (267), pl. 16 (42), fig. 8 ("Metatype").

Murex rufus compactus Gabb. PILSBRY, 1922, Acad. Nat. Sci. Phila., Proc., v. 73, p. 352, pl. 28, fig. 1 (Lectotype).

Diagnosis: "Shell short, thick, robust; spire about two-thirds as long as body whorl. Whorls eight; the first two nuclear, suture impressed. Body whorl broad above, tapering in advance, top sloping, very slightly concave. Varices three, short, robust, fimbriated or toothed on the margins, but bearing no spines or other elongate processes. Between each pair of varices, on the shoulder of the whorl, is a broad, blunt node. Surface ornamented by numerous large revolving ribs, between which are many smaller lines, all crossed by distinct, subsquamose lines of growth. Aperture small, sub-oval, inner lip with a faint tooth posteriorly; outer lip internally striate; canal short, blunt. Length 2.3 in.; width 1.4 in." (Gabb, 1873)

Lectotype: ANSP 3258.

Dimensions of lectotype: height 56.4 mm, diameter 32.3 mm (Pilsbry, 1922, p. 352).

Horizon: Gurabo Formation, Domincian Republic; middle Miocene.

Figured specimen: USNM 113775, height 36.5 mm, diameter 20 mm; locality, Potrero, Rio Amina, Dominican Republic.

Discussion: The type of this species from the middle Miocene of Santo Domingo was not figured until 1922 when Pilsbry published his *Revision of W. M. Gabb's Tertiary Mollusca of Santo Domingo.* As Pilsbry pointed out (1922, p. 306) Gabb selected a type series of specimens for his species. In the case of *C. compactus* the type lot consisted of five syntypes, all numbered ANSP 3258. Pilsbry's selection of this specimen would be the first valid selection of a lectotype.

Guppy (1876) and Dall, following him (1890), both placed *C. compactus* in the synonymy of *Murex textilis,* however there is little more than generic resemblance between the two species, and such a synonymy could never be justified. Even though the species had not been figured at the time of these workers there is little in Gabb's original description to suggest such a relationship.

Although Maury (1917, p. 267) cited this species in her work on Santo Domingo evidently no specimens were collected by the members of the expedition, for she stated: "Our shell is a metatype sent by Professor Gabb from Santo Domingo." The specimen figured here is from Potrero on the Rio Amina where the Maury expedition did little collecting because of "floods and rebels" (1917, p. 452). These beds were tentatively assigned to the upper formation, later named the Gurabo Formation by Maury (1919) and correlated with the middle Miocene Gatun Formation of Panama.

C. compactus is most closely related to *C. dujardinoides,* but may be distinguished by the presence of only one intervarical node. In addition, the varical laminae have a tendency to become divided into discrete spines, foreshadowing the appearance of these spines in *C. floridanus.* Whether these three species represent a direct line of evolution is not certain, but, rather, they are each representatives of a stage of development. It might be presumed that there was a direct link between the two northern species, and *C. compactus* is the southern analog of an as-yet unknown middle Miocene Florida species which would possess two intervarical nodes, and the same type of intermediate varical spines. *C. compactus* is more likely the immediate ancestor of *C. florifer,* with its single intervarical node.

CHICOREUS (CHICOREUS) VENEZUELANUS (F. Hodson)

Plate II, figures 1a, b.

Murex venezuelanus F. HODSON, 1931, Bulls. Amer. Paleontology, v. 16, no. 59, p. 37, pl. 18, fig. 1; pl. 19, fig. 1, 3.

Murex (Chicoreus) brevifrons Lamarck. WOODRING, 1959, U.S.G.S. Prof. Paper 306-B, p. 216 (in part, *not* of Lamarck).

Diagnosis: "The shell is large, heavy, and ornamented with conspicuous spines. The protoconch is missing; there are about 6 subsequent convex whorls; the angular shoulder on each whorl bears 3 strong varices with a weaker intervarical tubercle between them. On the body whorl below the angulation, on adult specimens, there are 3 stronger spiral cords which form spines on the varices; the two anterior of these form larger spines. All the whorls show a spiral sculpture of close-set threads, some being stronger than others. The outer lip shows about 12 internal lirae; the lirae on the anterior half of the lip may occur in pairs." (Hodson, 1931)

Holotype: PRI 24097.

Dimensions of imperfect holotype: height 78.5 mm, diameter 54 mm.

Type locality: Rio Codore, 4.65 kilometers north and 550 meters west of Urumaco, District of Democratia, Falcón, Venezuela.

Horizon: Uramaco Formation, Venezuela; middle Miocene.

Figured specimen: PRI 24101 (paratype), height 48.5 mm, diameter 30 mm; locality same as holotype.

Discussion: According to A. N. Dusenbury, Jr. *(in litt.),* who has been working on the stratigraphic assignments of the Hodson species, the type locality cited above occurs in the middle member of the Uramaco Formation of upper middle Miocene age. Although placed in synonymy with *C. brevifrons* by Woodring (1959, p. 216) this species is distinguished by several criteria. The first is the markedly appressed suture. The later whorls ride up over the earlier whorls to the base of the shoulder spine, whereas in *C. brevifrons* there are two major spines present on the median whorls. Furthermore the spines are more numerous in *C. brevifrons.* On the last three varices there are five major spines, of which the two posterior ones are much larger than the three anterior ones. In *C. venezuelanus* there are only three spines, one at the shoulder and the other two grouped together near the canal. The spiral ornamentation is also much stronger in *C. brevifrons* with strong cords leading to each of the five major spines, and smaller threads leading to the secondary spinelets. Compared with *C. brevifrons,* the intervarical area of *C. venezuelanus* is nearly smooth, possessing only faint spiral sculpturing.

C. venezuelanus is probably a descendant of *C. folidodes* (Gardner) and consequently also resembles the European *C. aquitanicus* (Grateloup). *C. venezuelanus* differs from both of these species in the smoother surface, and the appressed suture mentioned above. However there is an interesting parallel in development, for *C. venezuelanus* is much larger than *C. folidodes,* and the upper Miocene specimens of *C. aquitanicus* attain a much greater size than the middle Miocene ones. Specimens from the Vienna Basin are commonly over 100 mm in height. Presumably it was the European line which gave rise to the Recent Red Sea species, *C. virgineus* (Röding) (=*Murex anguliferus* Lamarck), but that common species more closely resembles *C. venezuelanus* than it does *C. aquitanicus.* In *C. virgineus* there are two small additional spines on the anterior portion of the varix, but the overall structure of the shell is remarkably similar. *C. virgineus* is variable, and there are forms especially close to *C. venezuelanus* in which the suture rides up on the previous whorls.

Chicoreus (Chicoreus) floridanus E. H. Vokes, n. sp.

Plate III, figures 1a, b, 2, 3.

Murex sexcostata Emmons, 1858, Rept. North Carolina Geol. Surv., p. 248, fig. 106. *Non Murex sexcostatus* Lamarck, 1816.

Murex brevifrons var. *calcitrapa* Lamarck. Heilprin, 1887, Wagner Free Inst. Sci., Trans., v. 1, p. 68 (*not* of Lamarck).

Murex (Chicoreus) brevifrons Lamarck. Dall, 1890, Wagner Free Inst. Sci., Trans., v. 3, pt. 1, p. 140 (*not* of Lamarck).

Murex (Chicoreus) rufus Lamarck. Maury, 1922, Bulls. Amer. Paleontology, v. 9, no. 38, p. 65 (95) (*not* of Lamarck).

Murex (Chicoreus) brevifrons Lamarck. Maury, 1922, Bulls. Amer. Paleontology, v. 9, no. 38, p. 66 (96) (*not* of Lamarck).

Murex (Chicoreus) rufus Lamarck. Gardner, 1948, U.S.G.S. Prof. Paper 199-B, p. 218 (in part, not pl. 29, fig. 23 = *C. dilectus*).

Murex (Chicoreus) brevifrons Lamarck. Olsson and Harbison, 1953, Acad. Nat. Sci. Phila., Mon. 8, p. 244, pl. 36, fig. 2 (*not* of Lamarck).

Murex (Chicoreus) salleanus Adams. Olsson and Harbison, 1953, Acad. Nat. Sci., Phila., Mon. 8, p. 244, pl. 36, fig. 1 (*not* of Adams).

Murex (Chicoreus) brevifrons Lamarck. DuBar, 1958, Florida Geol. Surv. Bull. 40, p. 196, pl. 12, fig. 1 (*not* of Lamarck).

Diagnosis: Shell large to moderate in size, whorls greatly inflated. Eight post-nuclear whorls in the adult; the nucleus, rarely preserved, consists of two smooth, bulbous whorls which terminate abruptly at a varix marking the initiation of ornamentation. Early axial ornamentation consists of small ribs at regular intervals, about 12 on each of the first two post-nuclear whorls. On the third post-nuclear whorl every third rib becomes strengthened to form a small varix, gradually increasing in size with each successive varix; three varices to one complete whorl. The two intervarical ribs continue as two nodes and persist as such up to the largest specimens seen. The spiral ornamentation on the first post-nuclear whorl consists of three equal cords; on the second to third whorls these are augmented by three smaller intercalary threads, and on the successive whorls additional threads appear. These threads are crossed by small axial growth lines which give a shagreened appearance to the entire surface of the shell. The three original cords persist as

spiral welts, but they are covered by finer threads, roughly alternating larger and smaller in size. On the body whorl there are usually nine of these welts, with six being on the body and three on the canal. On an adult specimen there are approximately nine larger threads from the crest of one spiral welt to the crest of the next. However the thread at the crest is no larger than the others. Where the spiral welts cross the varices, foliaceous spines are produced. The shoulder spine is somewhat wider than the others, but is not noticeably longer. The spines are open on the apertural side, and occasionally multiple layers are formed within the shoulder spine. There is a pronounced anal slit which is constricted at the edge of the aperture, so as to be almost invisible, but which opens behind the labrum. The siphonal canal is broad, recurved at the distal end, and almost covered over, however it remains open by a narrow slit.

Holotype: USNM 644823.

Dimensions of holotype: height 73 mm; diameter, excluding spines, 38 mm.

Type locality: TU 520, canal ⅓ mile east of Brighton, Highlands County, Florida.

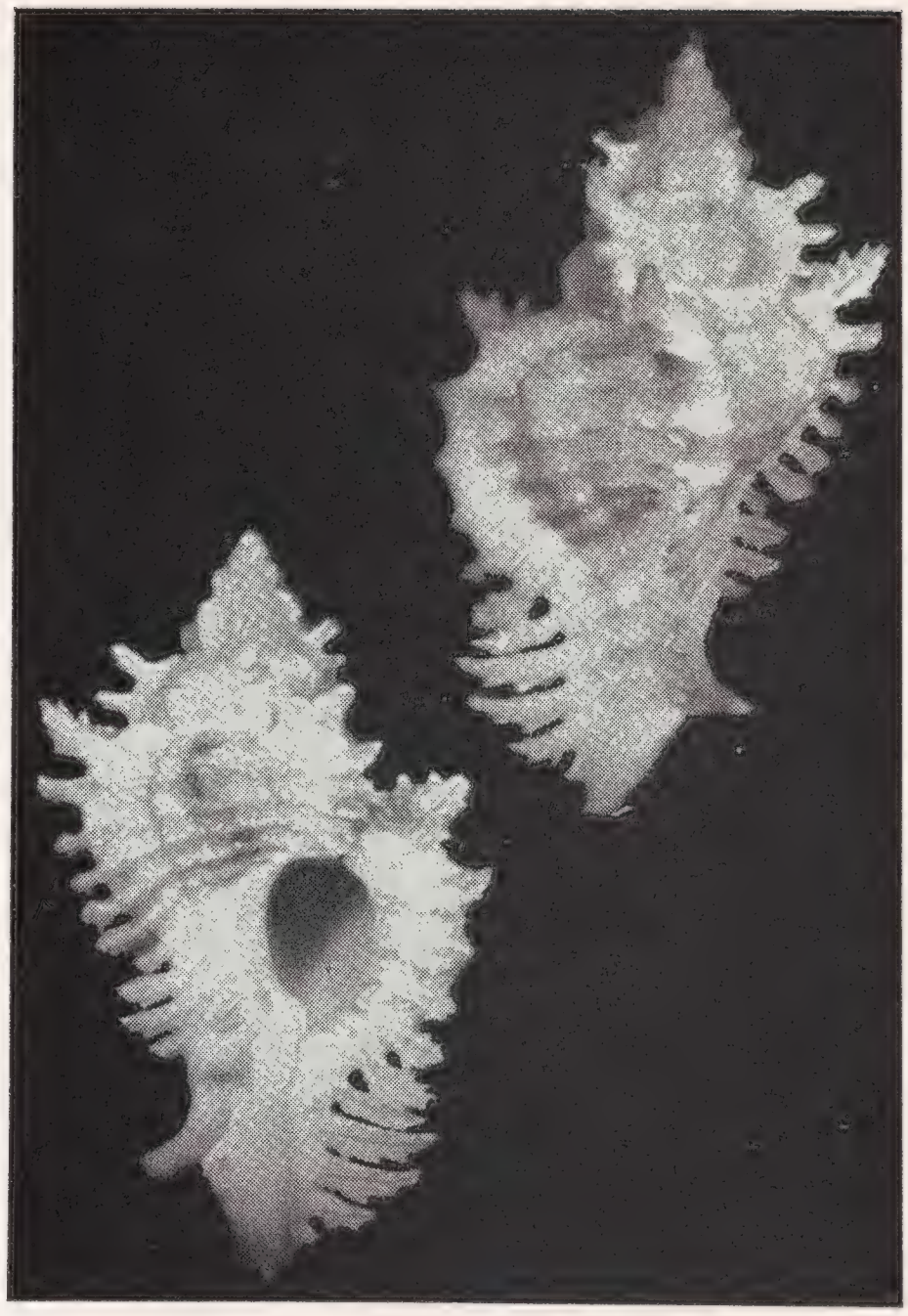
Horizon: Choctawhatchee Formation and Pinecrest Beds, Florida; upper Miocene. Caloosahatchee Formation, Florida; Waccamaw Formation, North and South Carolina; Pliocene.

Figured specimens: Fig. 1, USNM 644823 (holotype). Fig. 2, USNM 644824 (paratype), height 11.4 mm, diameter 6 mm; locality TU 60. Fig. 3, USNM 644825 (paratype), height 52 mm, diameter, excluding spines, 28 mm; locality TU 202. Other occurrences: TU locality nos. 60, 72, 79, 200, 202 (247 specimens), 203, 206, 519 (152 specimens), 520 (135 specimens), 521, 522, 523 (107 specimens), 525, 527, 528, 529, 531, 532, 536, 539B, 540, 541, 558, 579, 583.

Discussion: This ubiquitous species from the upper Miocene and Pliocene of the southeastern United States has been much misunderstood, as the synonymy above demonstrates. It is most closely related to *C. dilectus* (A. Adams) an equally misunderstood species from the Pleistocene and Recent of the same area. There are four species of *Chicoreus* in the later Cenozoic of the western Atlantic which have been repeatedly confounded. The four will be discussed separately in succession, in an attempt to make some sense out of the confusion which has persisted in the literature on the southeastern area. Three of these species occur in the Recent: *C. dilectus* (A. Adams), *C. brevifrons* (Lamarck), and *C. florifer* (Reeve). The first two also occur in the fossil record, *C. dilectus* in the Pleistocene (?) of Florida, and *C. brevifrons* in the Pliocene and Pleistocene south in the Caribbean region. *C. florifer* has not been reported occurring prior to the Recent. The only species which is found in the upper Miocene and Pliocene of Florida and the Carolinas is *C. floridanus.* The apparent cause of the difficulty in citation for this species is that it resembles both *C. dilectus* and *C. florifer* somewhat, but not enough to be unquestionably identified with either. Emmons (1858) was the first to report this species, but the name he used had been employed previously by Lamarck for a different form. Although two species have been reported from the "Caloosahatchee" beds by several authors (Dall, 1890; Maury, 1922; Olsson and Harbison, 1953), with large suites of specimens it is impossible to segregate two forms. The large, heavy adult specimens have been referred to *"Murex rufus"* or *"Murex salleanus"* and the small, light, long-spined, juvenile specimens have been referred to *"Murex brevifrons."*

The stratigraphy of the "Caloosahatchee" beds has only recently begun to be understood. In the past it has been commonly thought that all fossils found in southern Florida in the vicinity of the Caloosahatchee River and Lake Okeechobee were "Pliocene" in age. The problem of identical facies and deposition spanning an interval of time, combined with the almost complete lack of outcrop has led to confusion of fossils from beds that are now considered to be upper Miocene, Pliocene, and Pleistocene in age. As *C. dilectus* does occur in the Pleistocene of this area it has added to the misunderstanding of *C. floridanus.* Olsson (Olsson and Petit, 1964) is the first to publish an intelligent interpretation of the stratigraphy of the area. In that paper he established the Caloosahatchee Group, with an upper Miocene unit, the "Pinecrest beds"; a Pliocene "Caloosahatchee Marl"; and an as-yet unnamed upper unit, questionably late Pliocene or early Pleistocene. In view of the restriction herewith of *C. floridanus* to the Pinecrest and Caloosahatchee units of Olsson's stratigraphy, it is interesting to note that he observed: "Perhaps the most significant deduction derived at from present data is that contrary to a widely accepted view, the Caloosahatchee fauna is more closely related to that of the Miocene than it is to the Recent or Pleistocene." (1964, p. 513).

C. floridanus may be distinguished from *C. dilectus* by the presence of two small, equal intervarical nodes, instead of the one large node, with occasionally a second smaller axial rib, characteristic of *C. dilectus.* The shell of *C. floridanus* is wider proportionally than that of *C. dilectus,* and the spines are thinner and less frondose. The nature of the spiral sculpture is also different, with the surface of *C. floridanus* being covered by small threads that ride over the major spiral welts with no change in size. The spiral threads of *C. dilectus* are noticeably larger on the crest of the major welts. At the type locality (TU 520), where the "molluscan fauna shows many marked peculiarities of its own" (Olsson and Petit, 1964, p. 517), specimens of *C. floridanus* may attain an enormous size. One unfigured paratype measures 89 mm in height. Such large specimens are not found at most localities and the average adult measures 40 to 50 mm in height. A typical Caloosahatchee paratype (TU locality 202) is also figured (pl. III, fig. 3) for comparison with the oversized holotype.



Text figure 2. *Murex dilectus* A. Adams. (X 1) Lectotype: British Museum (Nat. Hist.) reg. no. 19659.

Chicoreus (Chicoreus) dilectus (A. Adams)

Plate III, figure 4, text figure 2.

? Murex pudoricolor Reeve, 1845, Conch. Icon., v. 3, *Murex*, pl. 33, fig. 171.
? Murex salleanus A. Adams, 1854, Zool. Soc. London, Proc., pt. 21 (1853), p. 70.
Murex dilectus A. Adams, 1856, Zool. Soc. London, Proc., pt. 23 (1855), p. 120.
? Murex salleanus Adams. Sowerby, 1879, Thes. Conchyl., v. 4, *Murex*, p. 19, pl. 9, fig. 73.
Murex dilectus Adams. Sowerby, 1879, Thes. Conchyl., v. 4, *Murex*, p. 18, pl. 6, fig. 60.
Murex florifer arenarius Clench and Pérez Farfante, 1945, Johnsonia, v. 1, no. 17, p. 34, pl. 19, fig. 1-3. *Non Murex sandbergeri* var. *arenaria* Steuer, 1912.
Murex (Chicoreus) rufus Lamarck. Gardner, 1948, U.S.G.S. Prof. Paper 199-B, p. 218, pl. 29, figure 23 (*not* of Lamarck, in part, = *C. floridanus*).
Not *Murex (Chicoreus) salleanus* Adams. Olsson and Harbison, 1953, Acad. Nat. Sci. Phila., Mon. 8, p. 244, pl. 36, fig. 2 (= *C. floridanus*).

Diagnosis: "M. testa ovato-fusiformi trivaricosa, carneola, rufescenti sparsim variegata, spira brevi, acuminata, anfractibus septum, varicibus foliaceo-fimbriatis ac laciniatis, interstitiis plicato-nodosis, transversim liratis liris rufo articulatis; apertura ovali, canali vix clauso, valde recurvato, labro margine crenato." (Adams, 1856)

Lectotype (here designated): British Museum (Nat. Hist.) reg. no. 1965-9.

Dimensions of lectotype: height 55 mm, diameter, excluding spines, 37 mm.

Type locality: Sanibel Island, Florida (after Clench and Pérez Farfante, 1945, p. 35).

Horizon: Unnamed post-Caloosahatchee formation, Florida; (?) Pleistocene. Recent, Gulf of Mexico and northern Caribbean.

Figured specimen: USNM 654369, height 54 mm, diameter, excluding spines, 26.5 mm; locality, off Long Boat Key, Florida (Recent). Fossil occurrences: TU locality nos. 201, 539A, 580, 582.

Discussion: The identity of this species, the most common *Chicoreus* in the Gulf of Mexico, has been confused by authors. It has been referred to *"Murex rufus,"* to *"Murex florifer,"* and to *"Murex salleanus"* to mention the most frequent citations. In 1945 Clench and Pérez Farfante proposed *M. florifer arenarius* for the form and thus it has become known in the succeeding interval. Unfortunately, that name is preoccupied by Steuer, 1912, and as a consequence another is required. A new one is not necessary as there is at least one valid name in existence for the species, and the possibility of two others. The most certain of these is *Murex*

dilectus A. Adams, which was described without locality. But the description is clear, and the subsequent illustration by Sowerby is so unmistakable that one wonders how this name has been overlooked. In the collection of the British Museum (Nat. Hist.) the type lot of *Murex dilectus* Adams consists of three specimens, two of which are the Florida species, the third is not. As Sowerby's illustration is clearly of the problem species, the largest of the three specimens, which closely matches the illustration, and may well be the one figured, is here selected as lectotype, and figured in text figure 2.

In addition to *C. dilectus* there are two other names which may apply to this species. The oldest of these is *Murex pudoricolor* Reeve. The original description of this shell from St. Thomas, Virgin Islands, sounds like this species, as it is small and "delicate blush-red in color." (The name *pudoricolor* means "blushing-color.") The type is not present in the British Museum (Nat. Hist.), but a small, pink specimen of *C. dilectus* is labelled *"Murex pudoricolor"* in the collection. However it is possible that this specimen may be misidentified. The juveniles of *C. argo* and *C. spectrum* are also pink so that the color is no valid criterion. As the exact identity of this species is not known, and as the only figured specimen is a juvenile, in this case it does not seem wise to select a lectotype, but rather the name should be considered a *nomen oblitum* and forgotten once again.

There is a second name, *Murex salleanus* A. Adams, which may possibly refer to this species. This taxon was described from Santo Domingo by Adams, and from the description and Sowerby's subsequent illustration, there is a strong suggestion that this is also the Florida species. However there is no type specimen, nor any other specimens which could be construed as type material, in the British Museum (Nat. Hist.). Sowerby's illustration shows a worn shell which could equally be *C. florifer,* as it was so considered by Clench and Pérez Farfante, or *C. dilectus.* For this reason it is deemed advisable to consider the name *Murex sallaneus* A. Adams as a *nomen dubium* in the interest of stability.

Clench and Pérez Farfante adequately differentiated this species from the similar *C. florifer,* except that the juveniles are not always pink. Brown apices are more common than the pink ones. *C. dilectus* may be distinguished from *C. florifer* by its narrower shell and generally lighter color. The shoulder spine of *C. dilectus* is approximately the same length as the other spines, although it may be much wider. The intervarical node is weaker, and occasionally a smaller second axial rib is present. Comparison with the ancestral species *C. floridanus* has been made already.

In passing it should be noted that the name *Chicoreus dilectus* has been used by Habe (1961, pl. 25, fig. 15) for a Japanese shell. This is not *C. dilectus* (Adams) but is *C. oligacanthus* (Euthyme).

Chicoreus (Chicoreus) brevifrons (Lamarck)

Plate III, figure 5

Murex brevifrons Lamarck, 1822, Anim. s. Vertèbres, v. 7, p. 161.

Murex calcitrapa Lamarck, 1822, Anim. s. Vertèbres, v. 7, p. 162. *Non M. calcitrapa* Lamarck, 1803, Eocene of France.

Murex brevifrons Lamarck. Kiener, 1843, Coquilles Vivantes, v. 7, p. 26, pl. 20, fig. 1.

Murex calcitrapa Lamarck. Kiener, 1843, Coquilles Vivantes, v. 7, p. 29, pl. 19, fig. 1.

Murex elongatus Lamarck. Reeve, 1845, Conch. Icon., v. 3, *Murex,* pl. 6, fig. 26 (*not* of Lamarck).

Murex purpuratus Reeve, 1846, Conch. Icon., v. 3, *Murex,* pl. 35, fig. 183.

Murex toupiollei Bernardi, 1860, Journ. de Conchyl., v. 8, p. 211, pl. 4, fig. 5.

Murex approximatus Sowerby, 1879, Thes. Conchyl., v. 4, *Murex,* p. 13, pl. 7, fig. 62.

Murex (Chicoreus) calcitrapa Lamarck. Gabb, 1881, Acad. Nat. Sci. Phila., Jour., (Ser. 2) v. 8, no. 4, p. 350.

Not *Murex brevifrons* var. *calcitrapa* Lamarck. Heilprin, 1887, Wagner Free Inst. Sci., Trans., v. 1, p. 68 (= *C. floridanus*).

Murex brevifrons Lamarck. Loiré, 1889, Geol. Reichs-Mus. Leiden, Samml., (Ser. 2) v. 1, p. 136, pl. 2, fig. 41.

Not *Murex (Chicoreus) brevifrons* Lamarck. Dall, 1890, Wagner Free Inst. Sci., Trans., v. 3, pt. 1, p. 140 (= *C. floridanus*).

Not *Murex (Chicoreus) brevifrons* Lamarck. Pilsbry, 1922, Acad. Nat. Sci., Proc., v. 73, p. 352 (= *C. cornurectus*).

Not *Murex (Chicoreus) brevifrons* Lamarck. Maury, 1922, Bulls. Amer. Paleontology, v. 9, no. 38, p. 96 (= *C. floridanus*).

Not *Murex brevifrons* Lamarck. Maury, 1925, Serv. Geol. Min. Brasil, Mon. 4, p.

138-139, pl. 6, figs. 7, 9 (= *C. cornurectus*).

Murex toupiollei "Born". TRECHMANN, 1933, Geol. Mag., v. 70, no. 823, p. 38.

Murex (Chicoreus) brevifrons Lamarck. CLENCH and PÉREZ FARFANTE, 1945, Johnsonia, v. 1, no. 17, p. 28, pl. 15, figs. 1, 2; pl. 16, figs. 1, 2.

Not *Murex (Chicoreus) brevifrons* Lamarck. OLSSON and HARBISON, 1953, Acad. Nat. Sci. Phila., Mon. 8, p. 244, pl. 36, fig. 2 (= *C. floridanus*).

Not *Murex (Chicoreus) brevifrons* Lamarck. DUBAR, 1958, Florida Geol. Surv., Bull. 40, p. 196, pl. 12, fig. 1 (= *C. floridanus*).

Not *Murex (Chicoreus) brevifrons* Lamarck. WOODRING, 1959, U.S.G.S. Prof. Paper 306-B, p. 216, pl. 35, figs. 11-13 (= *C. cornurectus*, in part).

Murex (Chicoreus) brevifrons Lamarck. WEISBORD, 1962, Bulls. Amer. Paleontology, v. 42, no. 193, p. 288, pl. 48, figs. 1, 2. Also ? p. 291, pl. 26, figs. 5, 6.

Diagnosis: "M. testa subfusiformi, ventricosa, crassa, ponderosa, transverse sulcata et striata, trifariam frondosa, alba, saepius lineis rubris cincta; frondibus brevibus; interstitiorum tuberculo maximo." (Lamarck, 1822)

"Type figure:" Martini, 1777, Conchy.-Cab. v. 3, pl. 103, fig. 983 (selected by Clench and Pérez Farfante, 1945, p. 30).

Type locality: St. Thomas, Virgin Islands (selected by Clench and Pérez Farfante, 1945, p. 31).

Horizon: "Korallenkalk" and "Riffkalk," Curaçao; Mare Formation, Venezuela; "Clay Beds," Costa Rica; Pliocene. Barbados, Pleistocene. Recent, western Atlantic, exclusive of Gulf of Mexico.

Figured specimen: USNM 654370, height 77 mm, diameter, excluding spines, 39 mm; locality unknown (Recent).

Discussion: As may be seen from the lengthy synonymy above, this species has been misunderstood not only in the literature of the Tertiary but also in that of the Recent. The original controversy arose with Lamarck who named two species: *Murex brevifrons,* from "l'Ocean americain," and *Murex calcitrapa,* with no locality. Kiener subsequently attributed a habitat of the Indian Ocean to *M. calcitrapa.* Later authors indicated a variety of Indo-Pacific localities for *M. calcitrapa,* but as best can be determined these are all based on either misidentifications or hearsay. No reliable reference for an Indo-Pacific occurrence has been found, either in the literature or in the collections of various museums. Most authorities agree that *M. brevifrons* and *M. calcitrapa* are synonyms, and the Caribbean locality is the only certain one. Since the time of Lamarck there have been a number of other species erected for shells which are indistinguishable from *M. brevifrons.* The writer recently had an opportunity to study the collections in the British Museum (Natural History) and to resolve many of the problems concerning this species. *Murex purpuratus* Reeve, an objective synonym of *M. brevifrons,* is based on a unique specimen, probably gerontic, in which the canal is twisted in a peculiar fashion. Neither *Murex toupiolleti* Bernardi, nor *Murex approximatus* Sowerby (=*Murex elongatus* "Lamarck" Reeve, not of Lamarck) can be separated. In addition to these three species, Clench and Pérez Farfante, in their monograph *The genus Murex in the Western Atlantic* (1945, p. 28) included under *Murex brevifrons* a number of species which are not synonyms. These are: *Murex pudoricolor* Reeve (which may be the same as *C. dilectus,* but is not the same as *C. brevifrons* as the juveniles of this species are not pink), *Murex megacerus* "Sowerby" Reeve (there is an error in numbering of Reeve's plate 6, and figures 24 and 25 are reversed; figure 24 is species 25, *Murex sinensis* Reeve, a valid Indo-Pacific form; and figure 25 is species 24, *Murex megacerus* Sowerby, a valid West African form; neither is *M. brevifrons*); *Murex crassivaricosa* Reeve (probably an Indo-Pacific species); *Murex alabastrum* A. Adams (the type of this species upon examination proves to be an *Aspella*); and *Murex adamsii* Kobelt (an unnecessary new name for *M. alabastrum* Adams, *non M. alabaster* Reeve).

As if this confusion in the Recent species were not enough, authors writing on the Tertiary of the western Atlantic region have elected to apply the name "*brevifrons*" to almost every *Chicoreus* found regardless of age or locality. Thus *C. cornurectus* and *C. floridanus* both are cited by this name. The only certain fossil occurrences of *C. brevifrons* are in the Pliocene Mare Formation of Venezuela (Weisbord, 1962) and the Pliocene of Curaçao (Lorié, 1889). This species has also been reported from the "Pliocene Clay Beds" of Costa Rica (Gabb, 1881) and from the Pleistocene of Barbados (Trechmann, 1933). The present distribution is throughout the Caribbean, and recently Bullis (1964, p. 105) extended the southern range to off the Amazon River in

Brazil. Clench and Pérez Farfante reported it off southern Florida but it is rare there.

Chicoreus (Chicoreus) florifer (Reeve)

Plate III, figure 6

Murex rufus Lamarck, 1822, Anim. s. Vertèbres, v. 7, p. 162. *Non Murex rufus* Montagu, 1803.
Murex rufus Lamarck, Kiener, 1843, Coquilles Vivantes, v. 7, p. 37, pl. 32, fig. 1.
Murex florifer Reeve, 1846, Conch. Icon., v. 3, *Murex*, pl. 36, fig. 188.
Murex (Chicoreus) florifer Reeve. Clench and Pérez Farfante, 1945, Johnsonia, v. 1, no. 17, p. 32, pl. 18, figs. 1-5.

Diagnosis: "Shell triangularly ovate, somewhat fusiform, transversely ridged, ridges rather distant, interstices very finely corded, cords scabrous over the back of the fronds, with a large elongated tubercle between the varices, three-varicose, varices very beautifully frondose, fronds erect, floriferous, muricated; whitish, more or less stained with rusty brown, fronds darker brown, muricated extremities of the fronds white within and without, apex pink." (Reeve, 1846)

Lectotype (here designated): British Museum (Nat. Hist.) reg. no. 1965-11 (Reeve, pl. 36, fig. 188).

Dimensions of lectotype: height 75 mm, diameter, excluding spines, 40 mm.

Type locality: Honduras (Reeve, 1846).

Horizon: Recent only, so far as known.

Figured specimen: USNM 654371, height 61 mm, diameter, excluding spines, 32 mm; locality unknown (Recent).

Discussion: C. florifer, although similar to *C. dilectus,* may be distinguished from that species by its larger average size and heavier shell. It also has one longer spine at the shoulder and generally more imbricated spines. There is only one intervarical node which is much stronger than that of *C. dilectus,* and the shell is proportionally wider at the periphery, giving it a triangular aspect. The shell is darker in color, ranging from a pale yellow body with dark brown fronds, as shown by Reeve, to a completely dark brown shell such as the one figured by Kiener, as *Murex rufus. C. florifer* probably represents a more warm water form of *C. dilectus* as the range is generally more southerly. Clench and Pérez Farfante reported this species from the Bahamas, southern Florida, the Antilles, and the coast of Central America. Those authors placed *C. salleanus* (Adams) in synonymy with *C. florifer,* which may or may not be correct, as previously discussed. They also placed *Murex despectus* Adams in synonymy, being misled by Adams' faulty locality data. Examination of the type in the British Museum (Nat. Hist.) reveals that it is, as most authors have agreed, a synonym of *Murex adustus* Lamarck (="*Purpura*" *brunnea* Link).

The type lot of *Murex florifer* Reeve in the British Museum (Nat. Hist.) consists of three specimens, one of which is that figured by Reeve. This figured specimen is here designated as lectotype. It is not refigured as the original figure by Reeve is entirely satisfactory.

Chicoreus (Chicoreus) argo (Clench and Pérez Farfante)

Murex (Chicoreus) imbricatus Higgins and Marrat, 1877, Literary and Philosophical Soc. Liverpool, Proc., v. 31, p. 413, pl. 1, fig. 2. *Non Murex imbricatus* Brocchi, 1814; *nec* Risso, 1826; *nec* Nardo, 1847.
Murex (Chicoreus) argo Clench and Pérez Farfante, 1945, Johnsonia, v. 1, no. 17, p. 31, pl. 17. New name for *Murex imbricatus* Higgins and Marrat.
Murex argo Clench and Pérez Farfante. Clench, 1953, Johnsonia, v. 2, no. 32, p. 360, pl. 178 (Holotype).

Diagnosis: "M. testa subelongato-fusiformi, transversim granoso-lirata, inter varices fortiter bi vel trituberculata, trifasciam varicosa, varicibus conspicue confertim frondosis, laciniato-foliosis, ad apicem spinosis, incurvis laminato-squammatis; columella laevi; aurantio lutescente, liris rufofuscis; apice rubescente." (Higgins and Marrat, 1877).

Holotype: Liverpool Museum.

Dimensions of holotype: height 82 mm, diameter 34 mm (Clench and Pérez Farfante, 1945, p. 32).

Type locality: Carinage, Island of Grenada, Lesser Antilles.

Horizon: Recent only, so far as known.

Discussion: C. argo is a rare shell and has been reported only twice since the original description by Higgins and Marrat. In 1949 Verrill reported a specimen taken off La Bime Point, Dominica, B.W.I., in a fish trap at a depth of between 30 and 50 fathoms. He subsequently figured a specimen (1950, pl. 10, fig. 2) from Soufriere Bay, Dominica, at 75 fathoms. According to Verrill, *C. argo* is a "deep red or reddish brown, with black concentric bands, with jet-black spines, and with a scarlet nucleus" (1950, p 127-128).

Sowerby in the *Thesaurus Conchyliorum,* v. 4, stated of *C. spectrum,* "I cannot doubt its identity with *Chicoreus imbricatus* of Higgins and Marrat." (1879, p. 14). The

differences in the two forms, although subtle, are sufficient to cause doubt in the mind of this writer. The type specimen of *C. spectrum,* if complete, would measure approximately five inches in height, or almost twice as big as the type of *C. argo* and the spire of *C. spectrum* is proportionally higher. *C. spectrum* is lighter in color, the body of the shell is pale yellow, with brown spiral lines, and only the fronds are dark brown. On the other hand, *C. argo* is nearly black, and is also dark within the aperture, which *C. spectrum* is not. *C. argo* has two or three distinct, rounded intervarical nodes, but *C. spectrum* has three rather indistinct axial ridges only.

Both *C. argo* and *C. spectrum* resemble the Miocene species *C. cornurectus.* They both have a much longer siphonal canal than any other western Atlantic species of *Chicoreus* and have one longer spine at the shoulder with three smaller spines. The depth records for the two species would seem to indicate that they inhabit deeper water than the other *Chicoreus* species, and, perhaps for this reason, they are not known from the fossil record.

CHICOREUS (CHICOREUS) SPECTRUM (Reeve)

Murex spectrum REEVE, 1846, Conch. Icon., v. 3, *Murex,* pl. 36, fig. 187.

Diagnosis: "Shell erectly fusiform, transversely ridged, ridges irregular, nodose and tuberculated, sutures of the spire rather excavated; three-varicose, varices thickened, frondose, fronds rather elongated, branched and muricated, canal rather long; yellowish, fronds and ridges chestnut-brown." (Reeve, 1846)

Holotype: British Museum (Nat. Hist.) reg. no. 1950-10-23-1.

Dimensions of imperfect holotype: height 113 mm, diameter, excluding spines, 49 mm.

Type locality (here designated): Dominica, British West Indies.

Horizon: Recent only, so far as known.

Discussion: Although *C. spectrum* was described without locality data, and it has never been reported in the literature, there are two specimens in the U. S. National Museum collection which are unmistakably this species. Both specimens were taken off Dominica, B.W.I. in 75 to 100 fathoms by A. H. Verrill. As no other locality is known for the species, Dominica is here designated as the type locality.

V. NOTES ON RECENT SPECIES OF *CHICOREUS (SIRATUS)*

The group of muricids typified by *Murex senegalensis* Gmelin was first distinguished by Jousseaume in 1880 (p. 335) as the genus *Siratus,* with the type species given as *"Purpura sirat"* Adanson. As Adanson is a pre-Linnaean author the first available name for this species is the one given by Gmelin, based on Adanson's plate 8, figure 19 (1757). Jousseaume did not give a description of his genus in the original citation but shortly after (?1882, p. 324) he provided the following:

> "Coquille à spire conique plus ou moins saillante; sur chaque tour 3 varices ailées en avant et armées d'épines simples ou ailées; entre chaque varice deux ou plusiers bourrelets; canal plus court que la hauteur de la spire, large à la base, effilé et coudé en avant; ouverture ovale avec un petit canal postérieur."

In the interval since the publication of the first part of this monograph (Vokes, 1963a) the author has had the privilege of studying the collections in the British Museum (Natural History). As is discussed further in the Introduction to the present paper, this study has convinced the writer that many species formerly assigned to *Murex* s.s. are better placed in *Chicoreus (Siratus).* The following notes refer to species treated in Part I—*Murex* s.s. of this monograph.

1. *Murex (Murex) aguayoi* Clench and Pérez Farfante, *M. cailleti* Petit, *M. ciboney* Clench and Pérez Farfante, *M. antillarum* Hinds, *M. motacillus* Gmelin, and *M. consulae* Verrill (=*M. pulcher* Adams), are all referred to *Chicoreus (Siratus).*

2. *M. cailleti* variety *kugleri* Clench and Pérez Farfante was a new name for *M. similis* Sowerby, 1841, *non* Schroeter, 1805. Examination of a series of specimens indicates that *M. similis* is a synonym of *M. cailleti* and this is an unnecessary name. However *M. elegans* Sowerby (see Clench and Pérez Farfante, 1945, pl. 9, fig. 5, 6) is not a synonym of *M. cailleti,* as stated by those authors, but is a distinct species characterized by having almost no spines, and with pronounced spiral brown lines equally spaced over the entire shell. As Sowerby's name is preoccupied by Donovan, 1804, by

Schlotheim, 1820, and by Wood, 1828, a new name is here proposed for this species:

CHICOREUS (SIRATUS) PERELEGANS,
nom. nov.

Murex elegans BECK *in* G. B. SOWERBY, JR., 1841, Conch. Illus., pl. 192, fig. 84.
Not *Murex elegans* DONOVAN, 1804, British Shells, v. 5, pl. 179, fig. 3.
Not *Muricites elegans* SCHLOTHEIM, 1820, Die Petrefactenkunde, p. 141 (*vide* ICZN Code, Art. 56b).
Not *Murex elegans* WOOD, 1828, Index Test., Suppl., p. 15, pl. 5, fig. 8.

A specimen of this species in the collections of the British Museum (Nat. Hist.) seems to be the one figured by Reeve (1845, pl. 24, fig. 99) although perhaps not the one figured by Sowerby in the original illustration. This specimen (height 65 mm) is here designated as lectotype. The "Island of St. Domingo, West Indies," cited as the locality for the shell figured by Reeve, is here designated as type locality.

3. Another species placed in the synonymy of *M. cailleti* by Clench and Pérez Farfante is *M. trilineatus* Reeve. This is also a valid species, most easily identified by the short spines and almost invariable three spiral brown lines. As the name is preoccupied by J. Sowerby, 1813, a new name is here proposed:

CHICOREUS (SIRATUS) REEVEI,
nom. nov.

Murex trilineatus REEVE, 1845, Conch. Icon., v. 3, *Murex*, pl. 25, fig. 103.
Not *Murex trilineatus* J. SOWERBY, 1813, Mineral Conch., v. 1, p. 80, pl. 35, fig. 4, 5.

The type lot of this species in the British Museum (Nat. Hist.) consists of three specimens. The specimen (height 58 mm) figured by Reeve is here designated as lectotype. The locality given by Reeve, "Gulf of Mexico," is here designated as type locality. The species is known to occur in Matanzas Bay, Cuba (author's collection).

4. *Murex (Murex) finlayi* Clench, also to be referred to *Siratus,* is a synonym of at least three older names. The first of these is *M. articulatus* Reeve, based on the figure given by Sowerby in the *Conchological Illustrations,* (1841) pl. 189, fig. 69, as "*Murex motacilla* variety." Reeve in the *Conchologia Iconia,* explanation to plate 22 (June, 1845), stated that Sowerby "published a drawing of another shell at Fig. 69, as a variety of *Murex motacilla,* which has little or no affinity with it, and which I propose to distinguish by the new title of *Murex articulatus.*" Two months later Reeve (*ibid,* August, pl. 25, fig. 107) named *Murex nodatus,* n. sp., explaining, "This shell was figured in the *Conchological Illustrations* by Mr. Sowerby as a variety of the *Murex motacilla.*" As there is a previous *M. nodatus* of Gmelin, 1791, this second name does not especially concern us, but the shell figured by Sowerby as "*M. motacilla* variety" which Reeve named *M. articulatus,* as well as that figured by Reeve as *M. nodatus,* are the same species as the one subsequently named *M. finlayi* by Clench. The third name given this species is *M. gundlachi* Dunker, described from Matanzas Bay, Cuba, the type locality of *M. finlayi.* Clench and Pérez Farfante placed all of these prior names for *M. finlayi* in the synonymy of *M. antillarum* Hinds, but comparison of the illustrations shows that the synonymy lies with *M. finlayi* not *M. antillarum.* The question of the *nomen oblitum* has not yet been satisfactorily resolved by the International Commission on Zoological Nomenclature, and at this writing there is a movement in the direction of not conserving a name less than 50 years old. In this case the name *M. finlayi* would not be a candidate for conservation, as it is only 10 years old, and *M. articulatus* Reeve would be the valid name for the species.

5. The name *Murex antillarum* Hinds is also threatened by an older name, *Murex formosus* Sowerby. This latter name has been considered by most authors as a synonym of *Murex rarispina* Lamarck on the basis of Kiener's statement (1843, p. 18) that *M. formosus* "n'est qu'une variété un peu plus large" of *M. rarispina.* The "*M. rarispina*" figured by Kiener (plate 11, fig. 1), stated to be from Lamarck's "Cabinet" and probably the shell which Lamarck had before him when he described *Murex rarispina,* is the same as Sowerby's *M. formosus.* However Lamarck had not figured his shell but referred only to a previously published figure: Martini, vol. 3, pl. 113, f. 1056. As his description is indefinite that figure has generally been taken as the type of *M. rarispina* rather than the Kiener figure. Unfor-

tunately, although Lamarck gave "Saint-Domingue" as his locality, the shell figured by Martini is Indo-Pacific, and is now known as *Murex trapa* Röding, based on the same Martini reference. Therefore although Kiener was correct in his evaluation, his synonymy cannot be accepted without creating nomenclatorial chaos, for the figures given by Kiener as *M. rarispina* and by Sowerby, as *M. formosus,* both are the species known today as *M. antillarum* Hinds. At the present time *M. formosus* may be considered a *nomen oblitum* until some final conclusion is reached as to the validity of that designation.

6. In addition to the above mentioned species which are to be referred to *Chicoreus (Siratus),* two new species from the Caribbean described recently by Bullis (1964) are also referable to this group. They are *Murex springeri* and *Murex thompsoni* from off the northeastern coast of South America.

VI. Rectifications in Nomenclature for Part I—*MUREX* s.s.

The controversial species, *Murex messorius* Sowerby, is apparently after all a West Coast form. Olsson has selected a lectotype (in press), from the specimens in the British Museum (Nat. Hist.), which is one of the *M. recurvirostris* complex, and so the western Atlantic species referred to *M. messorius* needs reidentification. All of the specimens in the British Museum which correspond to the Caribbean species now called *M. woodringi* Clench and Pérez Farfante are labelled "*M. nigrescens* Sowerby." Although that species was described from the western coast of Colombia (Xipixapi) there is always likelihood of mistaken locality data in any of the old Cuming collections. There is still the necessity for much more work on this entire complex and for the time the best solution would seem to be the use of the name *M. woodringi* for the Caribbean species which may or may not be the same as *M. nigrescens* Sowerby.

VII. Appendix I

References for Species Cited but not Treated in Systematic Descriptions

Murex adamsii, Kobelt, 1877, Deutsch. Malak. Gesell., Jahr., v. 4, p. 154. New name for *M. alabastrum* Adams, *non M. alabaster* Reeve.

M. adustus Lamarck, 1822, Anim. s. Vert., v. 7, p. 162.

M. alabaster Reeve, Conch. Icon., v. 3, *Murex,* pl. 10, fig. 39.

M. alabastrum A. Adams, 1864, Zool. Soc. London, Proc., 1863, p. 29.

M. anguliferus Lamarck, 1822, Anim. s. Vert., v. 7, p. 171.

M. aquitanicus Grateloup, 1833, Soc. Linn. Bordeaux, Actes, v. 6, no. 33, p. 94.

M. bourgeoisi Tournouër, 1875, Journ. de Conchyl., v. 23, p. 156, fig. 5, 5a.

"Purpura" brunnea Link, 1807, Naturlien-Samml. Univ. Rostock, v. 2, p. 121.

Murex calcitrapa Lamarck, 1803, Ann. Mus. Natl. Hist. Nat., v. 2, p. 223.

M. crassivaricosa Reeve, 1845, Conch. Icon., v. 3, *Murex,* pl. 9, fig. 33.

M. despectus A. Adams, 1854, Zool. Soc. London, Proc., pt. 21 (1853), p. 72.

M. dujardini Tournouër, 1875, Journ. de Conchyl., v. 23, p. 151, pl. 5, fig. 4, 4a.

M. formosus G. B. Sowerby, Jr., 1841, Conch. Illus., pl. 197, fig. 112.

M. gundlachi Dunker, 1883, Malak. Blatter, (N.S.) v. 6, p. 35, pl. 1, figs. 1, 2.

M. imbricatus Brocchi, 1814, Conch. Subap., v. 2, p. 408, pl. 7, fig. 13.

M. imbricatus Risso, 1826, Hist. Nat. Europe, v. 4, p. 196.

M. imbricatus Nardo (*ex* Chiereghini), 1847, Sin. mod. spec. Lag. Veneto, p. 55.

M. imperialis Fischer, 1807, Mus. Demidoff, v. 3, p. 198.

M. imperialis Swainson, 1831, Zool. Illus., (2) v. 2, pl. 67.

M. margaritensis Abbott, 1958, Acad. Nat. Sci. Phila., Mon. 11, p. 61, pl. 1, fig. n, o. New name for *M. imperialis* Swainson, *non* Fischer.

M. megacerus G. B. Sowerby, Jr., 1834, Conch. Illus., pl. 60, fig. 18.

M. nodatus Gmelin, 1791, Systema Naturae, ed. 13, v. 1, pt. 6, p. 3536.

M. oligacanthus Euthyme, 1889, Soc. Malac. France, Bull., v. 6, p. 269, pl. 7, fig. 2, 3.

M. ramosus Linnaeus, 1758, Systema Naturae, ed. 10, p. 747.

M. rarispina Lamarck, 1822, Anim. s. Vert., v. 7, p. 158.

M. rufus Montagu, 1803, Test. Brit., v. 1, p. 263.

M. sandbergeri var. *arenaria,* Steuer, 1912, Geol. Landesanst Darmstaat, Abh., v. 6, p. 21, pl. 2, figs. 6-9.

M. senegalensis Gmelin, 1791, Systema Naturae, ed. 13, v. 1, pt. 6, p. 3537.

M. sexcostatus Lamarck, 1816, Encyl. Méth., p. 9, pl. 441, fig. 3a, b.

M. sinensis Reeve, 1845, Conch. Icon., v. 3, *Murex,* pl. 6, sp. 25, fig. 24.

M. springeri Bullis, 1964, Tulane Stud. Zoology, v. 11, no. 4, p. 104, figs. 7, 8.

M. textilis Gabb, 1873, Amer. Phil. Soc., Trans., (N.S.) v. 15, pt. 1, p. 202.

M. thompsoni Bullis, 1964, Tulane Stud. Zoology, v. 11, no. 4, p. 103, figs. 3, 4.

M. trapa Röding, 1798, Museum Boltenianum, p. 145.

M. tricarinatus Lamarck, 1803, Ann. Mus. Natl. Hist. Nat., v. 2, p. 223.
M. trophoniformis Heilprin, 1887, Wagner Free Inst. Sci., Trans., v. 1, p. 107, pl. 15, fig. 40.
"*Purpura*" *virginea* Röding, 1798, Museum Boltenianum, p. 141.

References for species here referred to *Chicoreus (Siratus)* will be found in Part I—*Murex* s.s. portion of this monograph.

VIII. Appendix II

Locality Data

The following are Tulane University locality numbers:

60. Choctawhatchee Fm., borrow pits at Jackson Bluff, Ochlockonee River, (NW ¼ Sec. 21, T1S, R4W), Leon Co., Florida.
70. Chipola Fm., Ten Mile Creek, at bridge of Florida Highway 73, (NW ¼ Sec. 12, T1N, R10W), Calhoun Co., Florida.
72. Choctawhatchee Fm., Alum Bluff, Apalachicola River, (Sec. 24, T1N, R8W), Liberty Co., Florida.
79. Caloosahatchee Fm., Ortona Locks, Caloosahatchee River, (Sec. 27, T42S, R30E), Glades Co., Florida.
196. Chipola Fm., Ten Mile Creek, about ¼ mile upstream from bridge of Florida Highway 73, (NE ¼ Sec. 11, T1N, R10W), Calhoun Co., Florida.
200. Pinecrest Beds, borrow pits about one mile southwest of Acline, (Sec. 29, T41S, R23E), Charlotte Co., Florida.
201. Unnamed post-Caloosahatchee formation, spoil banks two miles south of Belle Glade, Palm Beach Co., Florida.
202. Caloosahatchee Fm., south bank of Caloosahatchee River, about two miles west of La Belle, (SE ¼ Sec. 12, T43S, R28E), Hendry Co., Florida.
203. Caloosahatchee Fm., north bank of Caloosahatchee River, about two miles east of Fort Denaud, (SW ¼ Sec. 11, T43S, R28E), Hendry Co., Florida.
206. Caloosahatchee Fm., junction of U. S. Highway 27 and Florida Highway 78, just west of Moore Haven, Glades Co., Florida.
453. Chipola Fm., Alum Bluff, Apalachicola River, (Sec. 24, T1N, R8W), Liberty Co., Florida.
457. Chipola Fm., west bank of Chipola River, about ½ mile below Ten Mile Creek, (SW ¼ Sec. 17, T1N, R9W), Calhoun Co., Florida. (Same as USGS 2213 and 3419, "One mile below Bailey's ferry.")
458. Chipola Fm., east bank of Chipola River, above Farley Creek, (Center Sec. 20, T1N, R9W), Calhoun Co., Florida.
519. Caloosahatchee Fm., Harney Pond Canal spoil banks, northwest side of Lake Okeechobee, (NW ¼ Sec. 18, T40S, R33E), Glades Co., Florida.
520. Pinecrest Beds, spoil banks, canal ⅓ mile east of Brighton, (SE ¼ Sec. 26, T37S, R32E), Highlands Co., Florida.
521. Pinecrest Beds, North shore Lake Okeechobee, Pumping Station no. 129,

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Plate I

Figures — Page

1a, 1b. *Chicoreus folidodes* (Gardner) X 1½ 184
USNM 644821; height 42 mm, diameter 24.8 mm.
Locality: TU 554. Chipola Fm., (?) lower Miocene.

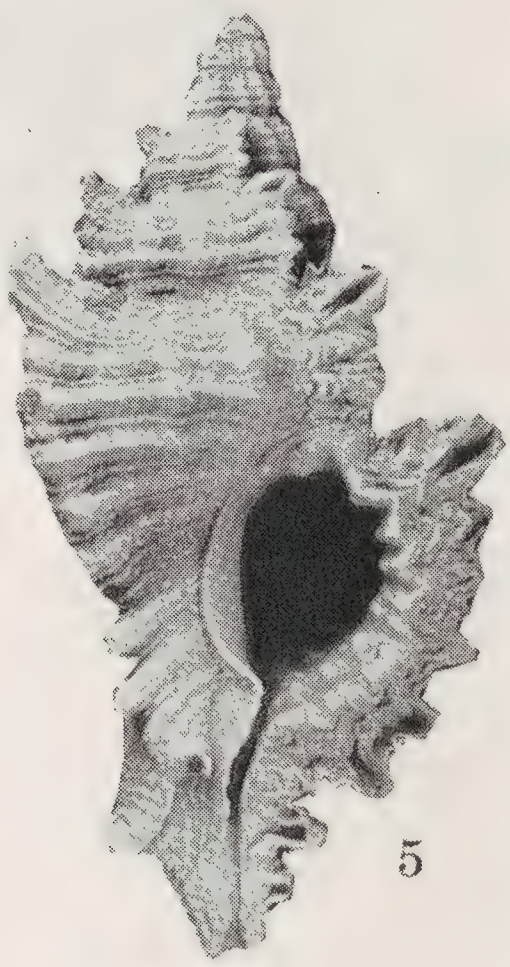
2. *Chicoreus aquitanicus* (Grateloup) X 1½ 184
Zurich 65/T/003; height 57 mm, diameter 30 mm.
Locality: Saubriques, near Dax, France. Helvetian.

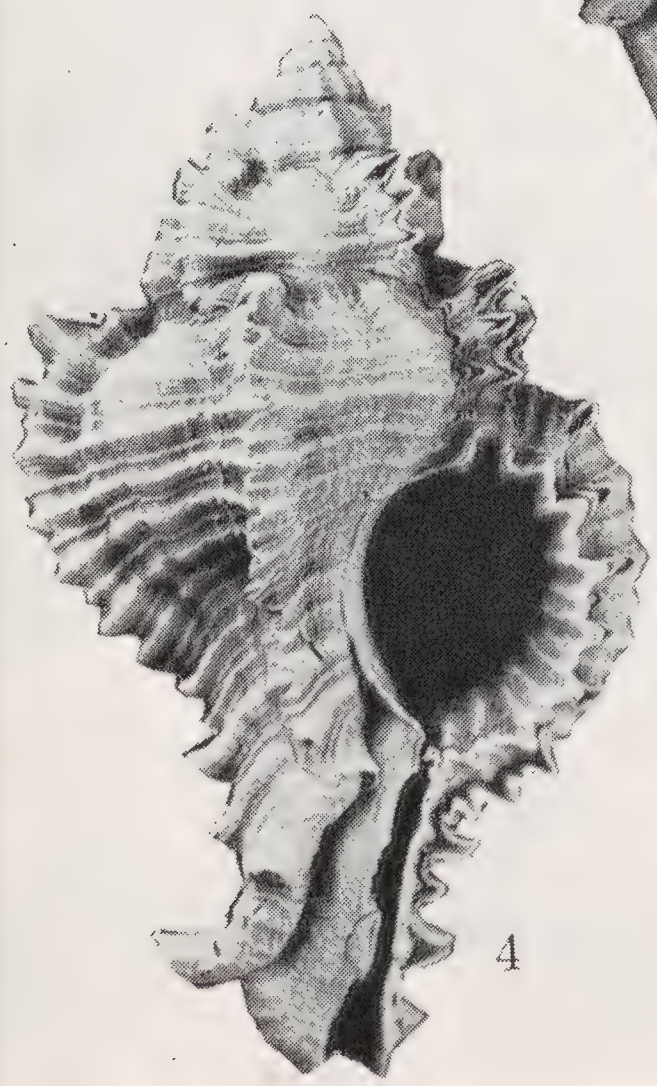
3. *Chicoreus bourgeoisi* (Tournouër) X 2 185
Zurich 65/T/002; height 33.3 mm, diameter 20 mm.
Locality: Pont Levoy, near Blois, France. Helvetian.

4. *Chicoreus lepidotus* (E. H. Vokes) X 2 185
USNM 644371 (holotype); height 34 mm, diameter 20 mm.
Locality: TU 544. Chipola Fm., (?) lower Miocene.

5. *Chicoreus dujardini* (Tournouër) X 2 186
Zurich 65/T/001; height 31.7 mm, diameter 16 mm.
Locality: Pont Levoy, near Blois, France. Helvetian.

6. *Chicoreus dujardinoides* (E. H. Vokes) X 2 185
USNM 644372 (holotype); height 32.5 mm, diameter 18.5 mm.
Locality: TU 547. Chipola Fm., (?) lower Miocene.





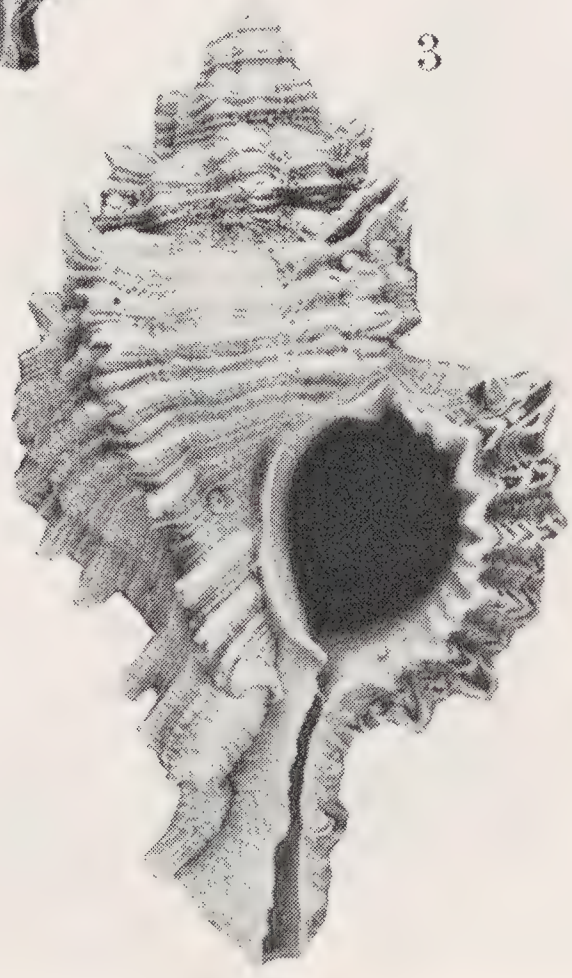


PLATE I

(NW ¼ Sec. 2, T40S, R33E), Glades Co., Florida.
522. Pinecrest Beds, Harney Pond Canal spoil banks, three miles northwest of Florida Highway 78, (NE ¼ Sec. 36, T39S, R32E), Glades Co., Florida.
523. Pinecrest Beds, Harney Pond Canal spoil banks, six miles northwest of Florida Highway 78, Brighton Indian Reservation, (NW ¼ Sec. 22, T39S, R32E), Glades Co., Florida.
525. Pinecrest Beds, U. S. Highway 41, at "Forty-mile Bend," Dade Co., Florida.
527. Pinecrest Beds, North shore Lake Okeechobee, Pumping Station no. 127, (NE ¼ Sec. 35, T39S, R33E), Glades Co., Florida.
528. Pinecrest Beds, Florida Highway 78, 5½ miles west of Indian Prairie Canal, (NW ¼ Sec. 9, T40S, R33E), Glades Co., Florida.
529. Caloosahatchee Fm., north bank of Caloosahatchee River, about two miles west of La Belle, (SE ¼ Sec. 12, T43S, R28E), Hendry Co., Florida.
531. Pinecrest Beds, spoil banks, canal crossing Florida Highway 771 about one mile west of Murdock R.R. Station, (SE ¼ Sec. 12, T40S, R21E), Charlotte Co., Florida.
532. Pinecrest Beds, spoil banks, canal 2½ miles southwest of Murdock R.R. Station, (SE ¼ Sec. 24, T40S, R21E), Charlotte Co., Florida.
536. Caloosahatchee Fm., south bank of Caloosahatchee River about one mile east of La Belle, (Sec. 3 & 4, T43S, R29E), Hendry Co., Florida.
539A. Unnamed post-Caloosahatchee formation, upper beds Shell Creek, about eight miles east of Cleveland, (Sec. 25, T40S, R24E), Charlotte Co., Florida.
539B. Caloosahatchee Fm., lower beds Shell Creek, same as above.
540. Caloosahatchee Fm., Miami Canal spoil banks, one to three miles south of pumping station at Palm Beach county line, Broward Co., Florida.
541. Caloosahatchee Fm., Miami Canal spoil banks, two miles north of pumping station at Broward county line, Palm Beach Co., Florida.
547. Chipola Fm., west bank of Chipola River, about ¼ mile above Four Mile Creek, (SW ¼ Sec. 29, T1N, R9W), Calhoun Co., Florida.
554. Chipola Fm., east bank of Chipola River at power line crossing, (SW ¼ Sec. 17, T1N, R9W), Calhoun Co., Florida.
558. Waccamaw Fm., marl pits at north end of Crescent Beach Airport, Crescent Beach, S. Carolina.
579. Caloosahatchee Fm., Miami Canal spoil banks, four miles north of pumping station at Broward County line, Palm Beach Co., Florida.
580. Unnamed post-Caloosahatchee formation, North New River Canal spoil banks, one mile south of South Bay, Palm Beach Co., Florida.
582. Unnamed post-Caloosahatchee formation, Rim Ditch spoil banks, just north of Florida-East Coast R.R. crossing, (Sec. 29, T36S, R39E), St. Lucie Co., Florida.
583. Caloosahatchee Fm., Miami Canal spoil banks, seven miles north of pumping station at Broward County line, Palm Beach Co., Florida.
655. Chipola Fm., Ten Mile Creek, about ½ mile down stream from bridge of Florida Highway 73, (NW ¼ Sec. 12, T1N, R10W), Calhoun Co., Florida.

The following are United States Geological Survey locality numbers:

USGS 3419. Chipola Fm., McClelland farm, one mile below Bailey's ferry, Chipola River, Calhoun Co., Florida (= TU 457).
USGS 8550. Gurabo Fm., Rio Gurabo, Dist. de Monte Cristo, Dominican Republic.

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Plate II

Figures — Page

1a, 1b. *Chicoreus venezuelanus* (F. Hodson) X 1½ 188
PRI 24101 (paratype); height 48.5 mm, diameter, 30 mm.
Locality: Rio Codore, near Uramaco, Falcón, Venezuela.
Uramaco Fm., middle Miocene.

2a, 2b. *Chicoreus cornurectus* (Guppy) X 2 186
USNM 644822; height 38.5 mm, diameter excluding spines, 20 mm.
Locality: USGS 8550. Gurabo Fm., middle Miocene.

3a, 3b. *Chicoreus compactus* (Gabb) X 2 187
USNM 113775; height 36.5 mm, diameter 20 mm.
Locality: Potrero, Rio Amina, Dominican Republic.
Gurabo Fm., middle Miocene.

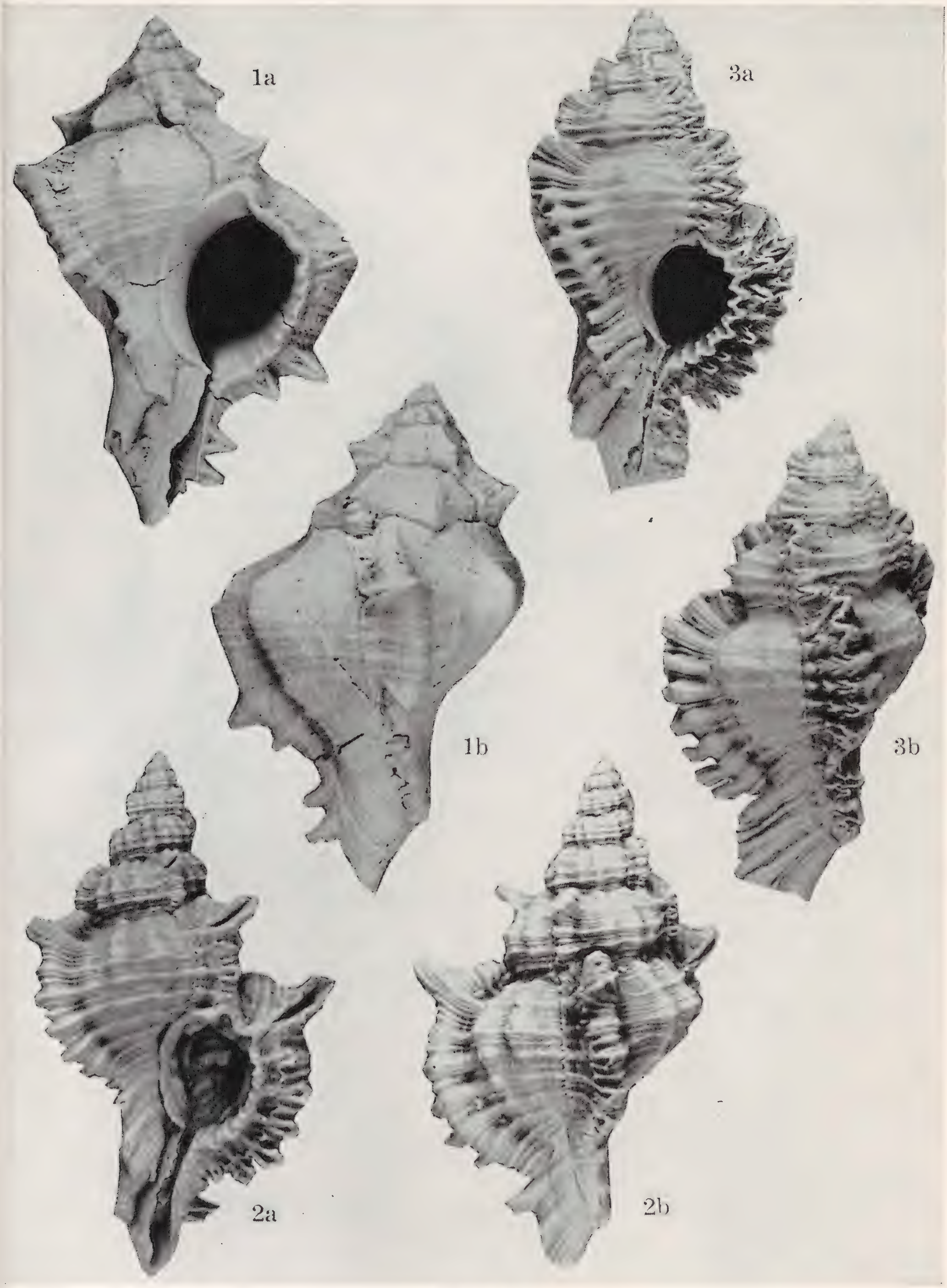

PLATE II

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PLATE III

Figures Page

1-3. *Chicoreus floridanus* E. H. Vokes, n. sp. ---- 189

1a, b. (X 1) USNM 644823 (holotype); height 73 mm, diameter, excluding spines, 38 mm.
Locality: TU 520: Pinecrest Beds, upper Miocene.

2. (X 4) USNM 644824 (paratype); height 11.4 mm, diameter 6 mm.
Locality: TU 60, Choctawhatchee Fm., upper Miocene.

3. (X 1) USNM 644825 (paratype); height 52 mm, diameter, excluding spines, 29 mm.
Locality: TU 202. Caloosahatchee Fm., Pliocene.

4. *Chicoreus dilectus* (A. Adams) X 1 ---- 191
USNM 654369; height 54 mm, diameter, excluding spines, 26.5 mm.
Locality: off Long Boat Key, Florida. Recent.

5. *Chicoreus brevifrons* (Lamarck) X 1 ---- 192
USNM 654370; height 77 mm, diameter, excluding spines, 39 mm.
Locality unknown. Recent.

6. *Chicoreus florifer* (Reeve) X 1 ---- 194
USNM 654374; height 61 mm, diameter, excluding spines, 32 mm.
Locality unknown. Recent.

PLATE III

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NOTE ON THE AGE OF THE CHIPOLA FORMATION (MIOCENE) OF NORTHWESTERN FLORIDA

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ABSTRACT

In recent years the Chipola Formation of northwestern Florida has been generally accepted as uppermost lower Miocene (Burdigalian) in age. However in the Chipola five species of Muricinae (Mollusca: Gastropoda) first appear which are most closely related to species described from the Helvetian of western Europe. Therefore the question is raised as to whether a younger age assignment for the Chipola and its correlatives is in order.

The philosophical aspects of correlation between the New World and the standard section of the European and Mediterranean area are well covered by Eames, *et al.* (1962). A portion of their discussion is worth quoting here in justification of any endeavor to improve the status of our New World correlation.

> "All stages of the Tertiary have their type localities within the region comprised by west and central Europe and the Mediterranean area, and these stages constitute the acknowledged, basic, fundamental standard of classification. These must remain the standard; all age determinations from other areas must be considered in direct relation to them, and are always open to reconsideration." (Eames, *et al.*, 1962, p. 2-3).

In the course of work on the species of Muricinae (Mollusca: Gastropoda), and especially of the genus *Chicoreus,* the writer has become dubious of the Burdigalian age assignment for the Chipola Formation of northwestern Florida.

The Chipola Formation was first described, although not named, by Langdon (1889), who measured the section at Alum Bluff, on the Apalachicola River in northwestern Florida. He cited 35 feet of "light yellow sand, containing pockets of fossils" at the base of the bluff (p. 322). After Langdon called attention to this section Mr. Frank Burns of the U. S. Geological Survey visited Alum Bluff, measured the section, and made a large collection of fossils. Burns also discovered that the fossiliferous beds which occurred at the base of Alum Bluff were exposed along the Chipola River[1] to the west of the Apalachicola. Here the fossils are in a much better state of preservation and, upon Burns' suggestion, Dall in 1892 proposed the name "Chipola marl" for these beds. At the same time Dall also proposed the name "Alum Bluff beds" for the non-fossiliferous sands and clays which overlay the Chipola Marl at Alum Bluff and underlay the fossiliferous upper strata (now Choctawhatchee Formation). The previous year (not seen: 1891, *fide* Wilmarth) Langdon had applied the name "Alum Bluff series" to the entire Miocene section at Alum Bluff, including both the upper and the lower fossiliferous horizons in his unit. Cooke and Mossom (1929, p. 138) stated that the "Alum Bluff series" of Langdon included only the Choctawhatchee horizon and that "Dall's 'Alum Bluff beds' and 'Chipola marl,' described in 1892, were under water at the time of Langdon's visit and were not discovered until December, 1889." A com-

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[1] "Bailey's Ferry," a classic locality in the geological literature was located at the mouth of Ten Mile Creek where a hard bed of the Tampa Limestone, which underlies the Chipola, is exposed just at river level. Here it was possible to drive a wagon down to the river without sinking up to the axles in Chipola mud. The cuts for the ferry approach are still visible, although overgrown.

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parison of the measured sections of Langdon, Burns, and later writers reveals that the entire section was given by Langdon, with the possible exception of the lowest portion of the basal bed, and that his "Alum Bluff series" did include those beds at the bluff which today are referred to the "Alum Bluff Group." (See also Vernon's discussion, 1942, p. 73.) Nevertheless Langdon's "Alum Bluff series" was never recognized and it was the "Alum Bluff beds" of Dall which Matson and Clapp (1909) raised to the rank of a formation with the Chipola Marl as a member. In 1926 Gardner gave the Alum Bluff the status of a group, with the Chipola as the basal formation.

The first age assignment made for the Chipola beds was "Miocene," to which age Langdon referred the entire Alum Bluff section. In 1892 Dall applied the term "Older Miocene" to all of the pre-Chesapeake Miocene (*i.e.,* pre-Choctawhatchee in Florida), including the Chipola Marl and the "Alum Bluff beds" in a "Tampa Group" which he proposed at the same time. Shortly thereafter, Dall (1896, p. 304) referred all of his "Older Miocene" strata of Florida and the Antilles to the upper Oligocene or Aquitanian, stating that "no strictly Miocene strata have yet been discriminated in the Antillean region," and "the strata of true Miocene in Florida are known to be extremely thin." (1896, p. 303-304). This age assignment was accepted until 1916, when Sellards proposed that the Alum Bluff beds should again be referred to the Miocene on the basis of certain vertebrate fossils, especially the protohippine horse *Merychippus.* Sellards judged the beds to be of lower middle Miocene age. (The beds in which Sellard's fossils were found are now referred to the Hawthorne Formation, usually considered as of lower and middle Miocene age. The Chipola may or may not be correlated with this part of the Hawthorne.) In 1919 Vaughan (p. 220) pushed the Alum Bluff Formation back down to the lower Miocene on the opinion of Prof. J. C. Merriam, who considered *Merychippus* "as the lower Miocene (Burdigalian) age." In 1926 Gardner began her series of studies on the molluscan fauna of the Alum Bluff Group and in the introduction she stated that "the detailed discussion of the stratigraphy will follow the systematic treatment of the fauna." (1926, p. 1). However it never appeared, and nowhere in the nine parts published over the next 25 years was there ever an age assignment given for any of the formations. Meanwhile, Woodring (1928, p. 90) followed Vaughan and gave the Chipola Formation an upper lower Miocene age, correlating it with the Quebradillas Limestone, and the Tuxpan, Thomonde, and Baitoa Formations of the Caribbean area. It is this correlation which has become the accepted standard for the western Atlantic region, and it was thus that it appeared in the Geological Society of America correlation chart (Cooke, *et al.,* 1943). In this chart it was noted that "Correlation with European stages is merely suggested. Exact correlation is not justified by the information at hand." (p. 1714). However a tentative Burdigalian assignment was made for the Chipola Formation.

There are four species of *Chicoreus* in the Chipola; *C. cornurectus* (Guppy), *C. folidodes* (Gardner), *C. lepidotus* (E. H. Vokes) and *C. dujardinoides* (E. H. Vokes). The two latter species are little more than stratigraphic subspecies (as, in fact, they were originally described) with *C. lepidotus* occurring in the lower beds of the Chipola, and *C. dujardinoides* in the upper beds. These two species are very close to the European Helvetian species, *C. bourgeoisi* (Tournouër) and *C. dujardini* (Tournouër) respectively. *C. folidodes* is also closely related to a species from the Helvetian of Euope, *C. aquitanicus* (Grateloup). Although Cossmann and Peyrot (1923, p. 122) considered *C. aquitanicus* as confined to the Tortonian, Glibert has reported this species from the Helvetian of Belgium (1952a, p. 90) and France (1952b, p. 290), and it is obvious from his illustrations that the Helvetian and Tortonian forms are the same. Specimens of *C. aquitanicus, C. dujardini,* and *C. bourgeoisi* are figured in the *Chicoreus* monograph preceding for comparison with their western Atlantic counterparts (plate I, figs. 2, 3, 5). The fourth species of *Chicoreus* in the Chipola, *C. cornurectus,* a common species in the Miocene of the Caribbean, especially Santo Domingo, also resembles *C. dujardini* and is presumably a close relative of that species.

One other muricine species in the Chipola, *Murex (Bolinus) vaughani* Maury, is also closely related to a European species, *Murex torularius* Lamarck, from the Helvetian and subsequent beds of the Mediter-

ranean area (see Vokes, 1963, p. 151). Thus we find in the Chipola five species of Muricinae that have no known American antecedents and which are much like species occurring in the Helvetian of western Europe.[2] The mechanism by which these European muricine species made their way to the New World is not known, nor why it should be that no more than these did make it. At this time no modern gastropod larvae are known to remain pelagic for a sufficient time to drift across the Atlantic Ocean. However, Thorson (1961) has suggested that among the truly "long-distance" larvae are those of the warm water, shallow dwelling, marine prosobranch gastropods, which would include the genus *Chicoreus.* Only a slight increase in current speed would permit the survival of these larvae for sufficient time to cross the Atlantic from West Africa to the Antilles. Today along the northwest coast of Africa we find at least three species of *Chicoreus* with four varices per whorl, a condition unique to this area. These, no doubt, are the descendants of the Miocene *C. bourgeoisi.* In fact authors (*e.g.* Nicklés, 1950) have used the name *C. bourgeoisi* for a Recent species, although the two forms are distinct. It is also along the West Coast of Africa that *Murex cornutus* Linnaeus occurs, a descendant of *Murex torularius.* Presumably the western extension of Africa played an important role in the migration route.

The fact remains that however they got across the Atlantic the presence of these species of European affinities in the Chipola fauna cannot be denied. This writer is of the opinion that five species from one subfamily alone are too many to be explained by any sort of parallel development. Their "sudden" appearance is most easily explained by migration from the eastern Atlantic and their similarity to the European species suggests that this migration occurred during Helvetian time. The evidence presented here is not conclusive but it does suggest that an upward shift in the relative position of the Chipola to conform to the European Miocene sequence may be indicated.

[2] There is also in the Chipola an undescribed species which most closely resembles *Typhis tripterus* Grateloup from the Helvetian of France and Hungary. This latter species has been referred to the subgenus *Nothotyphis* by Fleming (1962, Trans. Roy. Soc. New Zealand, v. 2, no. 14, p. 117). There is some question in my mind whether the group is to be considered as a subgenus of *Typhis* or of *Pterynotus* where it was placed by Fleming. Nevertheless this is one more link in the chain of evidence for a Helvetian age assignment for the Chipola.

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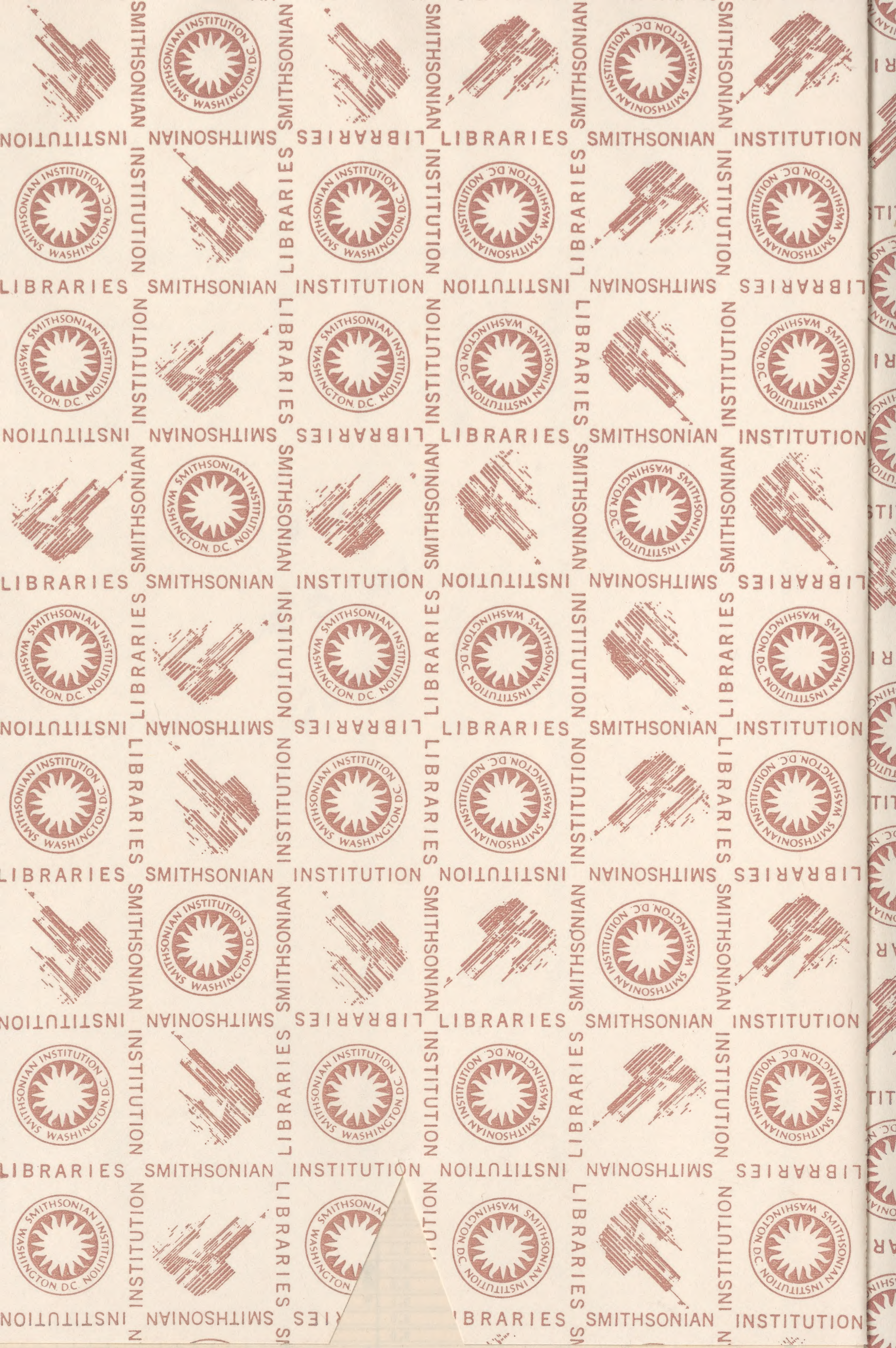
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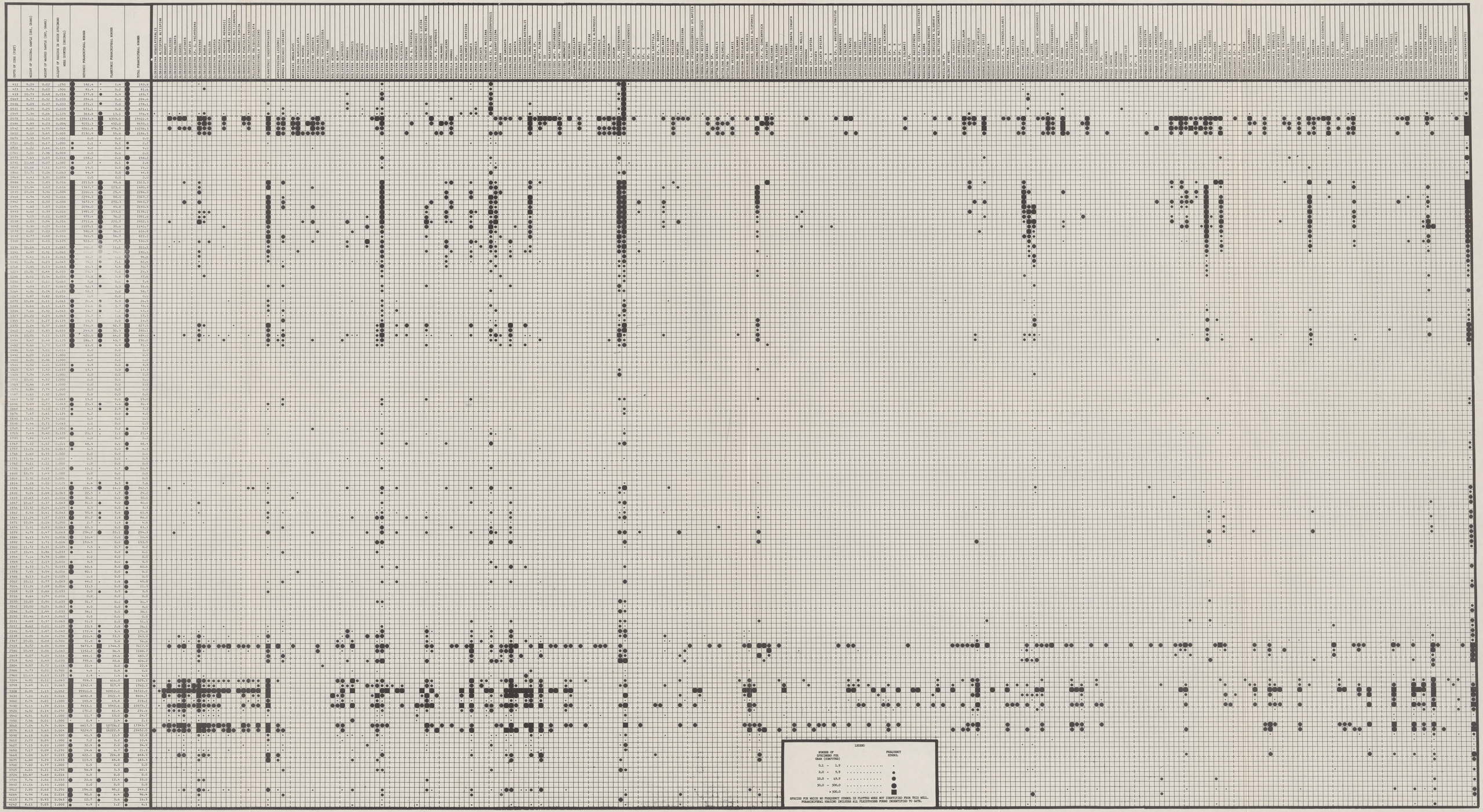

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